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ABSTRACT

This study investigated whether there is a relationship between first-grade children's ability to tell a story about a dynamic picture or a sequence of three dynamic pictures and their ability to describe the picture(s) with a number sentence. An 8x2 design allowed analysis of the effects of form of drawing, number of pictures, and response condition. Ninety-six randomly selected first graders were individually tested with a ten-item investigator-developed instrument. Statistical analysis indicated that neither drawing style nor number of pictures had a significant effect on either the level of assimilation within the stories, the perception of motion, or the number sentence responses. Analysis of the response condition revealed a significant difference favoring the force condition on number sentence responses. Also, initially viewing and interpreting sequences provided a learning experience which significantly affected the interpretation of single pictures. (Author/MS)

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The Role of Pictures in First Grade Children's Perception of Mathematical Relationships

Patricia F. Campbell

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FOREWORD

Ed Begle recently remarked that curricular efforts during the 1960's taught us a great deal about how to teach better mathematics, but very little about how to teach mathematics better. The mathematician will, quite likely, agree with both parts of this statement. The layman, the parent, and the elementary school teacher, however, question the thesis that the "new math" was really better than the "old math." At best, the fruits of the mathematics curriculum "revolution" were not sweet. Many judge them to be bitter.

While some viewed the curricular changes of the 1960's to be "revolutionary," others disagreed. Thomas C. O'Brien of Southern Illinois University at Edwardsville recently wrote, "We have not made any fundamental change in school mathematics."[1] He cites Allendoerfer who suggested that a curriculum which heeds the ways in which young children learn mathematics is needed. Such a curriculum would be based on the understanding of children's thinking and learning. It is one thing, however, to recognize that a conceptual model for mathematics curriculum is sound and necessary and to ask that the child's thinking and learning processes be heeded, it is quite another to translate these ideas into a curriculum which can be used effectively by the ordinary elementary school teacher working in the ordinary elementary school classroom.

Moreover, to propose that children's thinking processes should serve as a basis for curriculum development is to presuppose that curriculum makers agree on what these processes are. This is not the case, but even if it were, curriculum makers do not agree on the implications which the understanding of these thinking processes would have for curriculum development.

In the real world of today's elementary school classroom, where not much hope for drastic changes for the better can be foreseen, it appears that in order to build a realistic, yet sound basis for the mathematics curriculum, children's mathematical thinking must be studied intensively in their usual school habitat. Given an opportunity to think freely, children clearly display certain patterns of thought as they deal with ordinary mathematical situations encountered daily in their classroom. A videotaped record of the outward manifestations of a child's thinking, uninfluenced by any teaching on the part of the interviewer, provides a rich source for conjectures as to what this thinking is, what mental structures the child has developed, and how the child uses these structures when dealing with the ordinary concepts of arithmetic. In addition, an intensive analysis of this videotape generates some conjectures as to the possible sources of what adults view as children's "misconceptions" and about how the school environment (the teacher and the materials) "fights" the child's natural thought processes.

The Project for the Mathematical Development of Children (PMDC)[2] set out to create a more extensive and reliable basis on which to build mathematics curriculum. Accordingly, the emphasis in the first phase is to try to understand the children's intellectual pursuits, specifically their attempts to acquire some basic mathematical skills and concepts.

The PMDC, in its initial phase, works with children in grades 1 and 2. These grades seem to comprise the crucial years for the development of bases for the future learning of mathematics, since key mathematical concepts begin to form at these grade levels. The children's mathematical development is studied by means of:

1. One-to-one videotaped interviews subsequently analyzed by various individuals.

2. Teaching experiments in which specific variables are observed in a group teaching setting with five to fourteen children.

3. Intensive observations of children in their regular classroom setting.

4. Studies designed to investigate intensively the effect of a particular variable or medium on communicating mathematics to young children.

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[1] "Why Teach Mathematics?" The Elementary School Journal 73 (Feb. 1973), 258-68.

[2] PMDC is supported by the National Science Foundation, Grant No. PES 74-18106-A03.

5. Formal testing, both group and one-to-one, designed to provide further insights into young children's mathematical knowledge.

The PMDC staff and the Advisory Board wish to report the Project's activities and findings to all who are interested in mathematical education. One means for accomplishing this is the PMDC publication program.

Many individuals contributed to the activities of PMDC. Its Advisory Board members are: Edward Begle, Edgar Edwards, Walter Dick, Renee Henry, John LeBlanc, Gerald Rising, Charles Smock, Stephen Willoughby and Lauren Woodby. The principal investigators are: Merlyn Behr, Tom Denmark, Stanley Erlwanger, Janice Flake, Larry Hatfield, William McKillip, Eugene D. Nichols, Leonard Pikaart, Leslie Steffe, and the Evaluator, Ray Carry. A special recognition for this publication is given to the PMDC Publications Committee, consisting of Merlyn Behr (Chairman), Thomas Cooney and Tom Denmark.

Eugene D. Nichols
Director of PMDC

PREFACE

This publication is a doctoral dissertation in mathematics education, completed while the author was a graduate assistant for the Project for the Mathematical Development of Children. Financial support for this investigation was provided by PMDC; however, supervision of the research rested with the author's doctoral committee, not the Project. The doctoral committee consisted of Eugene D. Nichols (major professor), Merlyn J. Behr, Thomas Denmark, Robert Kalin, and Wolfgang Heil. It is hoped that this publication will provide the reader with some insight as to the influence of specific characteristics of textbook illustrations on children's interpretations of mathematical relationships.

Thanks are due PMDC administrative assistant, Janelle Hardy, and editor, Maria Pitner, for handling the publication of this dissertation.

THE FLORIDA STATE UNIVERSITY

COLLEGE OF EDUCATION

THE ROLE OF PICTURES IN FIRST GRADE CHILDREN'S PERCEPTION OF MATHEMATICAL RELATIONSHIPS

By
PATRICIA FORSYTHE CAMPBELL

A Dissertation submitted to the Area
of Instructional Design and Personnel
Development, Program of Mathematics
Education, in partial fulfillment of
the requirements for the degree of
Doctor of Philosophy

Approved:

Professor Directing Dissertation

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August, 1976

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ABSTRACT

This study investigated whether there is a relationship between first grade children's ability to tell a story about a dynamic picture or a sequnce of three dynamic pictures and their ability to describe the picture(s) by a number sentence. The artistic variables characterizing the pictures were controlled so as to provide information concerning which types of illustrations best facilitated interpretation of the pictures and perception of mathematical relationships. An 8 x 2 design allcwed analysis of the effects of the form of the drawing, the number of pictures, and the response condition. Ninety-six first grade children were individually tested using an instrument designed by the investigator. Statistical analysis revealed that neither drawing style nor the number of pictures had a significant effect on either the level of assimilation within the stories, the perception of motion, or the number sentence responses. Analysis of the response condition revealed a significant difference favoring the force condition on number sentence responses. Also, initially viewing and interpreting sequences provided a learning experience to significantly effect the interpretation of single pictures.

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I am deeply grateful to Dr. Eugene D. Nichols for his guidance and insight throughout this study. His encouragement in combination with patient supervision has contributed invaluably to this research effort. I wish to express my gratitude to Dr. Merlyn J. Behr for frequent consultation during the planning and execution of this study, as well as for serving as an experimenter during the data collection period. I also wish to thank the remaining members of my committee, Dr. E. Thomas Denmark, Dr. Robert Kalin, and Dr. Wolfgang Heil, for their suggestions.

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I wish to extend special acknowledgment to Dr. Cynthia A. Clarke and Mr. Stewart R. Wood who served as experimenters in this study. I also wish to thank the first grade teachers, Ms. Patricia Kitching, Ms. Sadette Lathrop, Ms. Gloria Smith, Ms. Cassandra Stephens, and Ms. Marsha Wolfel, and all their students who participated in the study. Their

cooperation was very much appreciated.

I am indebted to my husband Greg for expressing love and encouragement, bolstering my confidence, throughout my graduate study. With gratefulness, I dedicate this dissertation to him.

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CHAPTER I

RATIONALE AND PURPOSE OF THE STUDY

An examination of current primary mathematics textbooks reveals that one of their means of communicating mathematical concepts to children is by pictures, in conjunction with written number sentences. The pictures are intended to aid the children in determining what operation is to be performed in the related problem. Often the pictures themselves may supply sufficient information so as to provide an entire basis for the solution. For example, a dynamic picture may clearly suggest addition or subtraction and allow the child to determine the answer by simply counting the objects in the picture. The intent is that children make a transfer from the dynamic situation illustrated in the picture to the abstract number sentence accompanying the picture. However, it is initially necessary for the children to perceive the action or motion portrayed in the pictures before they can relate the pictures to the addition or subtraction sentences.

The National Science Foundation-supported Project for the Mathematical Development of Children (PMDC) has produced video-tape recordings of children interpreting mathematical concepts. Analysis of taped interviews recorded during 1974-75 has suggested that first graders offer varying interpretations of pictures depicting mathematical relationships and, at times, may become confused by the pictures.

Research concerning children's perception of pictures indicates that children initially perceive only discrete items depicted in a picture and gradually develop the ability to describe a picture in terms of overt action and to perceive relationships between the illustrated characters (Amen, 1941; Carpenter, 1964; Travers, 1969). Thus, the ability to interpret pictures may not be natural. As stated by Levie and Dickie (1973):

> In communicating with words it is obvious that if the receiver does not know the language he will not be able to decode the message. It is obvious that reading is a skill that must be learned. It is not obvious--indeed it is sometimes completely unnoticed--that a parallel condition exists in the case of pictures. Children must learn how to "read" pictures. (p. 865)

One of the more difficult representations for children to "read" in pictures is motion (Ames, Leonard, Metraux & Walker, 1953; Travers, 1969), yet perception of motion is necessary in order to interpret most pictures found in current primary school mathematics textbooks.

As noted by Travers (1969), little is known concerning what features within illustrations developed for instructional purposes best communicate the intended information to the student. Dwyer (1967) has called for research to identify those physical characteristics within particular types of illustrations which facilitate student achievement of specific educational objectives.

There is a need to investigate children's perceptions of mathematical relationships within textbook-type pictures. This study has investigated the following research questions. How do first graders interpret or "read" dynamic mathematics textbook pictures? Is there a correlation between the children's ability to interpret these pictures and their ability to characterize the mathematical relationships depicted in the pictures? What physical characteristics of these pictures best communicate mathematical relationships to the children?

The purpose of this study was to determine whether there is a correlation between first grade children's ability to verbalize a story which assimilated the characteristics of a two-dimensional picture and indicated perception of motion and their ability to characterize the mathematical relationship (either addition or subtraction) depicted in the pictures by a number sentence. Further, the artistic variables characterizing the pictures were balanced in order to investigate which types of illustrations best facilitated perception of mathematical relationships.

CHAPTER II

BACKGROUND FOR THE STUDY

Research regarding children's learning from pictures is generally indexed under the heading of perceptual learning in developmental psychology. In educational research, it is usually indexed under audio-visual materials, communication strategies, or instructional media. The diverse nature of these research studies presents a problem when attempting to review their findings. This problem is compounded further by the lack of integration between the psychological research and the application of their findings within an educational setting. Very few studies have directly investigated children's learning from pictures as it relates to the elementary school curriculum, and those studies have only considered the effect of pictures on reading skills. Research reports concerning the effect of pictorial representations on students' ability to solve typical ninth grade algebra word problems have been located and reported upon in this review; however, the investigator has not been able to locate any study relating pictures and the learning of primary mathematics.

This review of the literature is presented in eight sections. The first section presents a selected review of current psychological studies which investigated the role of imagery, comparing learning from pictures with learning from words. These studies dealt with (a) paired-associate tasks and (b) recall and/or recognition tasks. The results of a sequence of studies which investigated children's interpretations of progressively changing pictures are presented in the second section. The third section considers characteristics of pictures. Studies which investigated children's picture perception and preference are noted in sections four and five. Studies which investigated children's ability to perceive depth in static two-dimensional pictures are reviewed in section six. The seventh section considers the relationships between pictures and reading skills of preschool through intermediate grade children. The eighth and final section presents four studies which investigated the role of pictures in the solution of typical high school algebra word problems.

The Role of Imagery

Paired-associate Tasks

In a paired-associate task, a collection of discrete item pairs is succesively presented to the learner. The pairs are then removed and upon presentation of the first member of the pair (the stimulus term), the learner must recall or recognize the second member of the pair (the response term). The success of the learner is dependent upon the permanency of the association within the pairs (Levin, Note 1).

With young children, much of the paired-associate research has centered around presenting the paired items as words, as pictures of the items, or as picture-word pairs, systematically varying the concreteness both between and within the pairs (Rohwer, 1970). Research has rather consistently shown that pictures are superior as stimulus items over words for both children and adults (Deno, 1968; Dilley & Paivio, 1968; Levie, 1973; Paivio & Yarmey, 1966; Rohwer, Lynch, Suzuki & Levin, 1967; Levin, Note 2). For example, Dilley and Paivio (1968) used a paired-associate task with 120 nursery school, kindergarten, and first grade children to investigate the effect of pictures and words as both stimulus and response items. They found that pictures significantly facilitated learning as stimulus items, but that pictures had a negative effect as response items.

In addition to experimental manipulations of the physical properties of the associated items, the mediational link between the associated items has been extensively investigated. This mediation may be provided by verbal elaboration, where a verb or sentence is given to relate the items within the pair, or by pictorial elaboration, where a picture is presented depicting the interaction of the items within the pair (Rohwer, et. al., 1967). Variables such as the meaningfulness or appropriateness of the mediating structure imposed on the items (Rohwer, 1966; Rohwer & Levin, 1968), the presentation mode of the pictures (Everston & Wicker, 1974; Holyoak, Hogeterp & Yuille, 1972), and the systematic variation of verbal and pictorial elaboration (Odom & Nesbitt, 1974) have all been investigated.

It has been noted by some researchers that there may be a developmental trend in the effectiveness of the two modes of elaboration; verbal elaboration appears relatively more effective with preschool children but loses its advantage as the subjects increase in age and develop the ability to utilize imposed pictorial elaborations (Milgram, 1967; Reese, 1965, 1970; Rohwer, 1970). However, the imposed pictorial elaboration did facilitate learning with the preschool subjects when compared to no mediation. Reese (1970) has suggested six plausible explanations of the relative superiority of older children over younger children in pictorial learning; he prefers the rationale that the preschool child does not "read" the picture in such a way as to infer a relationship between the depicted items. For example, an adult may relate a pictorial elaboration as "the spoon is holding a candle," whereas, assuming that a child in fact labels the items, it may be as "a spoon and a candle." Rohwer (1970), on the other hand, hypothesized that verbal modes of representation develop earlier than pictorial modes. Other researchers have refuted that hypothesis (Bruner, Olver, Greenfield, Hornsby, Kenney, Maccoby, Modiano, Mosher, Olson, Potter, Reich & Sonstroem, 1966; Palermo, 1970). Still another interpretation has been investigated and documented (Cramer, 1975; Lynch & Rohwer, 1972; Milgram, 1967). These researchers have asserted that older children are more capable of attaching a verbal label to a pictorial stimulus and this double encoding, both verbal and visual, increases the likelihood of subsequent recall. All of these explanations are further complicated by recent research results which have failed to replicate a developmental trend in the ability to benefit from imposed pictorial elaboration (Everston & Wicker, 1974; Odom & Nesbitt, 1974).

In all of the paired-associate tasks with mediation referred to above, the mediating link was imposed upon the subject by the experimenter. That is, either a picture depicting interaction of the paired items or a verbal statement describing the interaction was provided by the experimenter. Other researchers have investigated associative learning when the subjects are instructed to generate their own sentences or visual images, relating the items in the pair in some way. Some generalizations concerning the development of visual imagery strategy may be suggested by this literature.

While children younger than 6 or 7 years of age are able to use an imposed elaboration effectively (Odom & Nesbitt, 1974; Reese, 1970; Levin, Note 2), they are usually unsuccessful when requested to generate an organizational strategy on their own (Jensen & Rohwer, 1965; Wolff & Levin, 1972; Levin, Note 2). This distinction seems to be greater for visual imagery than for generating sentences to associate items in a pair. Although a developmental study conducted by Jensen and Rohwer (1965) determined that kindergarten children did not benefit from induced sentence instructions as did second graders, a later study noted that 4 and 5 year olds had little difficulty producing sentences and, as shown by their performance on paired-associate tasks, were able to effectively utilize these sentences (McCabe, Levin & Wolff, 1974). Similarly Montague (1970) reported that her sample of inner city first graders was able to benefit from induced sentence instructions to the extent that their scores on paired-associate tasks did not differ significantly from the scores of subjects in the imposed pictorial or verbal conditions. However, the first graders were not able to benefit from an induced visual imagery strategy in associative-learning tasks (i.e. "make up a picture in your head of the two things in each pair doing something together"). By the age of 7 or 8, most children are able to benefit from instructions to form visual images (Danner & Taylor, 1973; Jensen & Rohwer, 1965;

Levin, Davidson, Wolff & Citron, 1973; Wolff & Levin, 1972). A study by Varley, Levin, Severson, and Wolff (1974) indicated that even though children between the ages of 5 and 7 do not appear to be able to utilize induced imagery instruction, they can acquire this skill with appropriate instruction involving manipulations of concrete materials. In summary, as stated by Levin (Note 1), evidence suggests that:

> The emergence of subject-generated sentence mnemonics as facilitative learning strategies may closely approximate the emergence of subject-generated dynamic imagery, the former preceeding the latter. (p. 5)

Recall and/or Recognition Tasks

Other studies investigating the role of imagery in learning have considered the differences between pictures and words as stimuli for memory retention tasks which do not require associative skills. In these studies, subjects are shown a sequence of items (presented as either pictures or objects or as written words naming objects) and, after a specified time span, the subjects are required either to identify the stimulus items from a larger collection of pictures and/or words (recognition) or to name the stimulus items when the stimuli are no longer present (recall) (Levin, Note 2).

Studies using adult subjects have revealed that people possess an extraordinary recognition memory for pictures, with a somewhat lessened capacity for recognition of words. For example, Shepard (1967) exposed adult subjects to three memory recognition tasks, each consisting of approximately 600 stimuli. Previously exposed words and sentences were recognized with about 89% accuracy; previously exposed pictures were recognized with about 97% accuracy. Care must be taken in interpreting these data since the word and picture lists were not identical in either length or content (the word list contained both nouns and adjectives). However, subsequent research with adults using simple line drawings and words of familiar objects (e.g. clock, house, bed, fish) has supported the superiority of pictorial representation over verbal labels in recognition memory (Jenkins, Neale & Deno, 1967; Paivio & Csapo, 1969).

Comparison of recall of verbal and pictorial stimuli is confounded by the fact that the recall response usually requires the subject to state or write the word identifying the stimulus. However, reports of recall studies utilizing adult subjects still tend to indicate that more pictures than words are recalled (Dallet & Wilcox, 1968; Liebermann & Culpepper, 1965).

Thirty-three preschool children (aged 3½ to 5 years) identified 44 pictorial stimulus items out of a field of 100 items with 98% accuracy on an immediate recognition task. Seven days later the subjects viewed 36 of the original stimuli in a field of 72 pictures; accuracy level on this delayed task was 73% (Brown & Scott, 1971). In a study with first graders, Entwisle and Huggins (1973) observed similar results with pictures depicting "unremarkable landscapes or cityscapes" (p. 392) and concluded that "young children can apparently process and retain a rather large amount of complex iconic information unrelated in any way to their ongoing activities" (p. 393). Young children have also been reported as being more successful on recognition items involving pictorial stimuli than with corresponding written word items (Corsini, Jacobus & Leonard, 1969).

In contrast to the results of studies using older subjects, Ducharme and Fraisse (1965) reported a nonsignificant tendency for children to recall more words than pictures when testing for written recall of words and pictures. Ducharme and Fraisse hypothesized that this result was due to the children's tendency not to label pictures, which resulted in an inability to retain pictorial stimuli as well as words. A follow-up study was then developed in light of this hypothesis. Feeling that a recognition task prior to the recall task (utilizing the same picture and word stimuli) would lessen the effect of non-labeling, Jenkins, Stack, and Deno (1969) administered both a memory recognition and a memory recall task involving 17 stimulus items to 116 second grade students. They found that the stimulus mode (picture or word) had no significant effect on the recall task but significantly more pictures than words were correctly identified in the recognition task--thus failing to reject the hypothesis offered by Ducharme and Fraisse. This investigation serves to underscore the inherent difference between recall and recognition tasks; success or failure in one form of memory retention need not predict performance on the other form (Mandler & Stein, 1974).

In an effort to further explore the nature of children's retention of pictorial stimuli, some researchers have begun to investigate recognition of reversals or orientation changes where the field distractor items are perceptually similar to the initial stimuli. Even preschool children have been found to be very successful in detecting orientation changes of items on matching-to-sample tasks (Stein & Mandler, 1975; Wohlwill & Weiner, 1964).

Brown and Campione (1972) presented 51 preschoolers (aged 3 to 5 years) with one of three recognition tasks (varying the length of retention period) involving pictures of people or animals. These tasks required the children not only to identify whether they had seen a picture of the character before, but also whether the character had been depicted "doing the same thing" in the stimulus item. Overall, the subjects recognized the stimulus items with a minimum of 85% accuracy. The accuracy of correctly identifying distractor items was consistently high for all retention periods (about 95%) whereas the ability to recognize stimulus items decreased significantly with longer retention periods from about 93% to 75% accuracy. The probability of correctly classifying a character as engaged in an identical task decreased significantly over time; however, there was not significant change over time in the ability to correctly classify similar items.

Mandler and Stein (1974) found that 7 and 8 year old children were very capable of recognizing left-right reversals of meaningful pictures (reflection on the vertical axis), averaging 91% correct. These pictures contained a number of objects; half of the pictures depicted the objects randomly spaced whereas the remaining pictures depicted a meaningful relationship between the objects in the pictures. Reversal within these pictures required a location change as well as an orientation change.

In a follow-up study, children aged 5 to 7½ years viewed a picture depicting three nonrelated geometric objects. The children later participated in the recognition task viewing the initial stimulus and nine transformed pictures in a random sequence. Two of the nine distractor cards depicted location changes as well as left-right orientation changes; the other seven distractors contained only orientation changes. The children were not only asked to identify whether each of the 10 pictures was the same as the initial stimulus, but they were also asked to tell how a "different" picture varied from the stimulus. One interesting result of this study was that these subjects were less apt to mention changes in orientation when location changes also occurred; however, if orientation was the only change, they were able to verbalize it. This study indicated that young children can code and retain orientation information. As more objects within the picture underwent a change in orientation, recognition improved becoming virtually perfect when coupled with a location change (Stein & Mandler, 1974). A subsequent study utilizing both real and geometric figures in similar orientation recognition tasks noted no significant difference in recognition accuracy due to picture type and obtained the same results as the studies noted above (Stein & Mandler, 1975).

Summary

Much of the research in psychology concerning how people learn from pictures is focused upon comparisons with how people learn from words. Many of these studies are based upon traditional verbal learning tasks; pictures are substituted for words and verbal responses are noted. Other investigations have measured non-verbal responses to pictures by eye movement (Mackworth & Bruner, 1970) or by "same"-"different" judgments within recognition or matching-to-sample tasks.

Perhaps if any generalizations can be made regarding the results of these studies, they would be in the following terms: pictures are better stimulus items than words in paired-associate learning tasks; items to be associated should be presented in some kind of a meaningful context rather than as isolated items; pictorial recognition is superior to recognition memory for words; with adults, free recall of pictures surpasses free recall of words, but this may not be the case for young children. There is a very definite chance for error within the generalizations above as they are based upon comparisons between studies. Such comparisons will only be valid if the different pictures used by the studies are equivalent.

This raises the question of what equivalent pictures are, that is, what differences or variables within pictorial stimuli affect learning and hence should be held constant or controlled between the pictorial stimuli within an investigation. Unfortunately, such variables are not clearly defined. As an explanation of this deficiency, Levie (1973) suggested that:

> The general lack of evidence relating pictorial stimulus variables to learning effectiveness may be due to the predominance of research designs that measure only intended, not possible, outcomes. (p. 42)

Children's Interpretations of Progressively Changing Pictures

In 1967, Schnall began a series of studies investigating children's interpretations of progressively changing pictures; in particular, the research probed for developmental differences in the verbal description of changes of an object depicted in different states. Subjects ranging from first graders to college students viewed sequences of pictures depicting a figure or figures being displaced along a line in a succession of discrete steps. The figures involved were either geometric forms (circle, triangle, oval) or concrete forms (stick figures). Other variables included color, number of pictures in the sequence, presence or absence of anchoring background features, and the number of figures in any given picture.

The verbal descriptions of the subjects were classified as either subordinate or discrete. Subordinate descriptions were characterized by the use of active verbs to describe the progressive change of the figures (e.g. to roll, to move, to grow). In these descriptions each figure within the pictures was viewed as a single entity undergoing a change and the series of pictures served to display the figure's position over time. Discrete descriptions, characterized by forms of the verb "to be," did not attribute any change or movement to the figures but rather described the physical mode of each discrete picture (e.g.

"There was a stick-figure here, a stick-figure here, and another one over here."). Schnall maintained that these two types of descriptions reflected a different perception of the sequence. This supposition was supported by the observation that subjects' drawings of the sequence differed systematically as a function of the type of description provided by the subject (Schnall & Kemper, 1968).

This series of studies revealed that spontaneous subordinate descriptions were more frequently offered by older subjects (11 year olds or college students) than by younger children (6 or 7 year olds) when the figure depicted in the sequence was a geometric form, but that this age difference tended to disappear when the same figure displacements were portrayed by stick-figures. Schnall suggested that this may mean that the concept of motion or change in the young child is dependent on his own experiences of change or motion by familiar objects (Kasdorff & Schnall, 1970; Schnall, 1968; Schweitzer & Schnall, 1970).

Characteristics of Pictures

Gibson's theory of pictorial perception (1971) defines a picture as "a display of optical information" (p. 83) and classifies it as a surrogate since it is produced by one person in order to relate an object, place, or event not present to another individual whose perceptions are, in turn, aroused by the picture. As surrogates produced by people, pictures involve a distortion of the objects or events they represent since they portray the artist's conception or perception. This distortion may be intensified if the viewer is not able to perceive the picture as intended by the artist. Perception is relative as man is a selective perceiver. That is perception is dependent upon what the individual has learned about his environment and what his current interest or frame of reference is when he views a picture (Berelson & Steiner, 1964); at the same time, man is incapable of attending to all potential stimuli simultaneously (Forgus, 1966). Applied researchers also have recognized the active role of the perceiver in the perceptual process (Dawson, 1964; Gregory, 1966). In a recent survey of pictorial research, Hanes (1975) stated that perception may be affected "not only by the variables inherent in the stimulus array, but also by those attributes of the learner involved in the perceptual process" (p. 12).

Pictorial materials may vary along many dimensions. Fidelity is the degree to which a picture provides a viewer with "sensory input" similar to that which he would have if he were viewing the scene represented by the picture (Travers & Alvarado, 1970). Fidelity is one dimension by which pictures may vary. Another dimension is the presence or absence of settings in which the central objects are presented. The amount of detail (color, line drawings, shading, photographs, etc.) and the influence of three-dimensional cues are other dimensions. The extent to which a picture is stylized or realistic is yet another dimension. Stylized representations are characterized by use of adopted convention codes to portray features which, as judged by the code, represent the real world even though they deviate from the real optical code. Cartoons are stylized pictures as are many illustrations in elementary school textbooks (Travers, 1969).

While cartoons typically rely on a stylistic representation of the face, textbook illustrations commonly use stylized conventions to signify movement. Very few elementary school textbook illustrations are designed to suggest a still scene. It is necessary for the student to convert the still picture into a dynamic action-filled scene in order to derive from it all the information which the illustrator has attempted to transmit. The static picture must be viewed as an instance that has emerged from previous events and as an instance which is leading up to and causing new events. Three conventions typically employed to infer motion in static pictures are to depict a moving object as blurred, to represent the moving object in a state of non-equilibrium, or to draw vibration or wake lines behind the moving object (Travers, 1969; Travers & Alvarado, 1970).

Friedman and Stevenson (1975) investigated developmental changes in the understanding of implied motion with 102 subjects (preschool through college age). Each subject viewed 45 line drawings of stick-figures and classified them as "still" or "moving." The line drawings depicted moving figures by the blurring or vibration convention (cartoon cues), by showing parts of the body (usually the limbs) in varying positions (postural cues) or by showing parts of the body in multiple positions. Many of the figures which depicted a postural position other than that defined as still were in the state of equilibrium. This may have been a confounding factor within the study. Regression analysis indicated that reliance on the cartoon cues increased with age while reliance on the postural cues decreased with age. Preschool and first graders saw significantly more figures utilizing postural cues as moving.

Children's Perceptions of Pictures

Hagen (1974) suggested that before an observer is able to perceive pictures, he must, among other things, disregard the static nature of the world presented by the picture, infer the meanings of size, shape, and distance cues, and understand and use symbolic conventions regarding form.

When confronted by a picture, what does a child notice? Which features are singled out as figures and which features are absorbed by the background field? Interpreting data collected by Ames and her associates (1953) as to how 50 children from ages 2 through 10 responded to the Rorschach test, Travers (1969) noted that the first "genuine percepts" based on the blot involved details and, as the children grew older, they began to correctly perceive the blot as a whole. This interpretation of the Ames' study by Travers is consistent with the findings of the many studies of figurative perception conducted by Elkind (1969). As summarized by Elkind:

> With increasing age, the child is better able to reverse figure and ground, to integrate parts and wholes and to scan configurations in more systematic, complex and novel ways. In short, our data suggest that the course of perceptual growth is marked by an increasing tendency to act upon any given configuration so as to perceive all of its many and varied facets. (p. 24)

Although the studies by Elkind and by Ames indicate that children are able to perceive wholes by the mid-elementary grades, there is a danger in generalizing their results from artificial experimental materials to the visual stimuli used in the classroom. Observational studies using typical illustrations suitable for children have noted three levels of sequential growth in children's ability to interpret pictures, namely: enumeration (naming or identifying the objects in the picture); description (describing the picture in terms of an overt action or quality); and, interpretation (perceiving relationships and inferring emotional states, evaluating ideas, and drawing conclusions). The level of interpretation is dependent upon the ability, experience, and maturity of the child, as well as his age (Amen, 1941; Carpenter, 1964; Gray & Klaus, 1965).

Miller (1938b) conducted an investigation to determine what third grade children spontaneously saw in pictures. One-hundred children were individually shown six pictures from textbooks suitable for their grade level and asked to tell the experimenter "all the things you see in it, what you think when you are looking at it, and what you think is happening in the picture" (p. 282). No time limit was imposed. The mean identification level per child was one-third of the potential number of items within each picture; however, only 19.5% of the potential identifications, including relationships between the characters in the picture, were noted by the children. Only in one picture were more than half of the subjects able to correctly identify the theme of the illustration. The children tended to view the items within the picture in isolation, rather than as parts of a unified whole. Miller suggested, on the basis of these results, that if pictures were to be of value in a learning experience, teachers would have to direct their students' attention to the important items in the picture and to develop the interpretation of these items.

Using unambiguous representations of real situations, Travers (1969) also investigated the development of children's pictorial perception. Sixty subjects, ranging from nursery school children through sixth graders, viewed six photographs (half in color; half in black and white). The procedure used was to present each picture to each child for a quarter of a second and then to ask him what he had seen. This procedure was repeated 10 times for each picture. Travers assumed that this technique of momentarily exposing the entire picture over a period of time would provide an indication of how the child assimilated the information within the picture. The results indicated a significant increase in the number of identifications as age increased. Younger children (nursery and kindergaten subjects) tended to become preoccupied with a specific detail and repeat that identification over and over, ignoring the remaining aspects of the picture. The proportion of errors for all subjects tended to be larger for black and white pictures than for the color pictures, particularly in terms of identification of themes and of motion. Motion was rarely perceived by the younger children in comparison to their object identifications; however, their limited perception of the entire picture would lower the probability of noting dynamic relationships within the photographs.

In a follow-up study, Vollan (1972) investigated whether the indicated superiority of color pictures over black and white pictures for communicating themes and motion was due to the simple presence of color or to the increased realism which natural color pictures convey. Twenty-four slides depicting common scenes were developed. Half of the slides depicted dynamic situations involving motion (e.g. a child walking, a dolphin jumping); the remaining slides pictured static events (e.g. a boat at a dock, a boy holding a bat). Each slide was developed in three ways: (a) using an authentic color reproduction process, (b) using a black and white reproduction process, and (c) using a contrived color reproduction process. The contrived pictures did not present color in a realistic manner (e.g. blue skies were pictured as being red). Ninety sixth graders viewed a set of 24 slides balanced across each picture development type. The students were shown a slide for one-half of a second and, immediately after viewing each slide, these students were asked to write what they had seen. Analysis of the results revealed that not only color, but also the degree to which the color represented reality led to an increased perception of motion. Authentic color pictures conveyed motion more often that either black and white or contrived color pictures; black and white pictures conveyed motion more often than contrived color pictures.

These studies suggest that primary and preschool children have difficulty relating the characteristics of pictures in terms of theme and motion, thus limiting their ability to perceive the dynamic nature of pictures.

Children's Picture Preference

The typical procedure for investigating children's picture preference varies from displaying a series of illustrations and asking the children to rank or rate the pictures to a comparison by pairs technique, whereby the children choose the preferred picture from pairs of pictures eventually forming a ranking of all the available pictures. Studies on children's picture preference have noted that children prefer pictures depicting action (Bamberger, 1922; Hildreth, 1936; Whipple, 1953) and involving people, places, or incidents with which they are familiar (Waymack & Hendrickson, 1932; Williams, 1924).

Other picture preference studies indicated that children prefer color pictures over black and white pictures (Amsden, 1960; Bamberger, 1922; Bloomer, 1960; Freeman & Freeman, 1933; Hildreth, 1936; Mellinger, 1932; Waymack & Hendrickson, 1932) and saturated color over light tints (Bamberger, 1922; Clegg, 1968; Freeman & Freeman, 1933). However, color is more appealing if it is realistic (Rudisill, 1952; Stewig, 1974; Whipple, 1953), even to the extent that children preferred uncolored realistic illustrations over unrealistic colored illustrations (Rudisill, 1952). This preference for realistic over stylistic or impressionistic pictures has also been noted by other researchers (Clegg, 1968; Hildreth, 1936; Mellinger, 1932).

French (1952) noted that 6 and 7 year old children typically drew pictures which were characterized by even, unaccented, unbroken outlines with localized color, without variations in shading, within the outlines of flat, two-dimensional, familiar objects. The complexity of children's drawings generally increased with age until, at about 11 years of age, children drew pictures with sketchy, irregular outlines of varied emphasis with shaded color, utilizing conventions of size, overlap and attempts at linear perspective to portray three dimensions. Classifying these types of drawings as simple and complex, French composed 13 pairs of illustrations, with each pair portraying the same scene in either a simple or complex manner. These illustrations were shown to 696 elementary school children who chose the preferred picture from each pair. Results indicated that the younger children preferred the simpler pictures (81% of the first graders; 84% of the second graders) while older children preferred the complex pictures. A reversal in preference from simple to complex illustrations occurred in the fourth grade where only 30% of the choices were for the simple illustrations. Bamberger (1922) and Stewig (1974) also found that young children preferred pictures with fewer details.

The preference for complexity in older children may be related to their increased capacity to deal with perceptual complexity. Travers and Alvarado (1970) hypothesized that "a child prefers the most complex presentations that he is able to organize perceptually" (p. 59). This statement must be interpreted carefully, however, for Travers (1969) also found that when highly familiar objects were involved, second graders displayed an ability to recognize pictorial stimuli at a level comparable to that of adults. The familiarity of the depicted items or scenes as well as the artistic features employed affect the perceptual complexity of a picture.

Depth Perception in Static Two-dimensional Pictures

In order to perceive or "read" pictures it is necessary to interpret and organize the symbolic elements of the lines and shadings along the conventions utilized by the artist. This is particularly true when attempting to make three-dimensional inferences about two-dimensional representations. Among the several devices commonly used to indicate depth are: (a) familiar size, (b) overlap, and (c) linear perspective. The familiar size cue indicates distance by drawing the larger of two known objects with smaller dimensions. This convention is often used in conjunction with linear perspective as the farther object is depicted on a higher level than the closer object (sometimes termed the elevation cue), as measured from the base of the drawings, and lines known to be parallel within the object or setting are drawn as converging lines. Overlap refers to the convention of superimposing nearer objects over farther figures, obscuring portions of the figures which are at a distance (Deregowski, 1972; Munroe & Munroe, 1969).

Much of the research concerning depth perception from line drawings has centered around investigations utilizing Hudson's pictorial depth perception test, developed for studies with African subjects. The test consists primarily of line drawings of three figures: a hunter, an antelope, and an elephant. The procedure involves asking the subject to name the depicted figures and to identify which of the three figures was nearer. Hudson (1960) originally administered his test to 11 different samples in South Africa, ranging from illiterate adult mine workers to white sixth graders. His results indicated that those subjects whose background and home life favored frequent exposure to pictures scored higher on the test; however, all of the subjects had difficulty perceiving depth from the pictorial stimuli. Numerous studies have since been undertaken using Hudson's test with different cultural groups. These studies indicated that children of most cultures provide two-dimensional responses (e.g. Deregowski, 1968; Mundy-Castle, 1966; Munroe & Munroe, 1969; Satterly, 1968). At least one study using Hudson's test indicated a possible relationship between the level of formal education and pictorial depth perception, as well as noting that the overlap cue seemed to be less dependent on formal education than the size cue

(Kilbride, Robbins & Freeman, 1968).

Many researchers have since suggested that Hudson's results may not be due to the subjects' misperceptions of conventional depth cues, but rather to the nature of the line drawings employed. Their subsequent studies involved variations on Hudson's test by rephrasing the questions, changing the depicted animals to a picture of a cow and a goat, and removing motivational influences. Comparison of subjects' scores on Hudson's test with these varied forms revealed significantly higher scores on the revised forms (Hagen, 1974; Munroe & Munroe, 1969; Omari & Cook, 1972; Omari & MacGinitie, 1974; Segall, Campbell & Heskovitz, 1966).

In a series of studies at Indiana University, the development of children's ability to utilize size, overlap, aerial perspective, and linear arrangement cues has been under investigation. Oh (1969) showed 180 elementary school children (aged 3 to 11 years) 20 photographic prints each depicting three objects and utilizing one depth cue. The children were asked to choose the object closest to them for each print. A significant effect due to age was noted with the following developmental trend: from ages 3 to 5, an understanding of length cues develops; overlap, size, and aerial perspective cues develop from age 5 to 6; and, by age 9, depth is perceived equally well by all four cues. In a similar study, Baikie (1970) investigated the effect of single perspective cues (size, overlap, or length arrangement) and combinations of those cues on the perception of depth from black and white pictures by 5 and 6 year olds. Age and socioeconomic class had significant effect, as did the depth cues. The length arrangement cue resulted in a significantly higher depth perception score than did either size or overlap; the combination of all three cues was more effective than any other cue combination. Instruction in utilizing the depth cues of size, overlap, and linear arrangement has also been shown to be effective for 5 and 6 year olds when measured immediately after instruction (Dilawar, 1971).

Other studies have tended to support the research at Indiana in the following sense: preschool children have difficulty interpreting depth cues, but increasing age and schooling has significant impact; at or about 6 years of age, children begin to perceive depth in static two-dimensional pictures, particularly when size cues are present (Brown, 1969; Jahoda & McGurk, 1974a, 1974b; McGurk & Jahoda, 1974; Wilcox & Teghtsoonian, 1971; Wohlwill, 1962).

The Effects of Pictures on Reading

Research concerning the effect of pictures on reading falls into two categories, namely, the effect of pictures on learning to read words and the effect of pictures on comprehension of written passages. All of the studies reported here consider pictures as an adjunct to the written or oral text.

Studies by Braun (1969), Harris (1968), and Samuels (1970) noted that young children acquired sight vocabulary faster under a word-only condition than when pictures and words were used simultaneously. Samuels (1970) conducted his study under both laboratory conditions and within a classroom. In a laboratory condition, 30 kindergarteners were randomly assigned to two groups where they learned to read four words (boy, bed, man, car). One group was instructed using only the printed words; the other group was instructed through the use of picture-word cards. During the testing situation, the children were asked to read the words when no picture was present. The no-picture group excelled. A similar study was conducted within a first grade classroom. Twenty-six matched pairs of students received special reading material suitable for first graders with seven months of reading instruction. Half of the subjects had material with a reading passage on the right face of a "book" and a picture depicting the theme of the story on the left face; the remaining students had only the reading passage with the left face of the "book" being blank. After classroom reading instruction, a posttest was administered. Results indicated no significant difference between the picture and no-picture condition for better readers. However, poorer readers in the no-picture condition learned significantly more words than the poorer readers in the picture condition; that is, the presence of a picture seemed to interfere with the acquisition of sight vocabulary among poorer readers.

Samuels' study under laboratory conditions taught the students to read a list of four unrelated words. King and Muehl (1965) also investigated the influence of pictures on learning sight vocabulary. They found, as did Samuels, that kindergarten children who were taught to read a list of four unrelated words (gate, drum, nest, fork) using only printed word cards were more successful at reading the words than were students who were taught to read the words when pictures were present. However, they noted the opposite trend when the subjects were taught to read a list of similar words (doll, ball, bowl, bell). Teaching methods involving picture-word cards were more effective for learning to read similar words than was instruction using only printed word cards.

Underwood (1963) suggested the principle of least effort as an explanation of why pictures interfere with learning to read words. The learning task set up by these studies may be viewed as basically a paired-associate task using the stimuli of a picture (which could elicit the desired response) and a word (which could not initially elicit the response). The picture was intended to prompt the verbal response for the word. However, the children need not shift the "stimulus control" from the picture to the printed word as, due to the principle of least effort, they may opt to only select that aspect of the dual stimulus which most easily elicits the correct response. Without the transfer of attention to the printed stimulus, sight vocabulary is not acquired.

Miller (1938a) investigated the effect of pictures on the reading comprehension of 600 first through third graders. The subjects were matched within classrooms on reading test scores; half of the students in each classroom received the adopted basal reader while the other students received the same reader only all of the pictures were covered. After only one semester of instruction, a reading comprehension test and an achievement test were administered. The results indicated no significant difference in scores on either test between the picture and the no-picture groups. However, these results may be misleading as Miller administered a rather unique comprehension test. The procedure required the children:

> To choose, from a group of words, a word spoken by the teacher; to select a phrase from two phrases when one was spoken by the teacher; to cross out an extraneous word from a group of three words; to complete a sentence after reading a paragraph; and to put in proper sequence the happening recorded in a paragraph to be read. (p. 678)

Using middle class second grade subjects, Weintraub (1960) also investigated the effect of pictures in basal readers on comprehension. The students read three stories from their text either with or without an accompanying picture. Multiple-choice examinations constructed by Weintraub were administered to measure comprehension of the main points of the stories. These tests each consisted of 10 items dealing with the movements, descriptions, and rationale for conduct of the characters in the stories. Weintraub reported that the comprehension scores were higher when the pictures were not present.

Strang (1941) had fourth through sixth graders read six passages (half were illustrated, half were not) and, after reading each passage, answer four questions designed to measure comprehension. He found that individual comprehension scores on the illustrated passages were higher than on the non-illustrated passages. Unfortunately, Strang did not control for order of presentation effects; the illustrated condition always succeeded the non-illustrated condition.

Vernon (1953, 1954) reported on a series of studies to determine the effect of pictures on the recall and comprehension of written passages. Subjects involved in these studies ranged from 10 to 18 years of age. Based on these investigations, she concluded that "the pictorial illustration in general had little effect upon the understanding and recall of verbal material" (Vernon, 1954, p. 177). Pictures may serve to enhance the recall of some facts, but, they may also serve to distract the reader from acquiring the "general gist" of a passage (Vernon, 1964).

In 1968, Koenke investigated the relationship between a picture and the comprehension of the main idea of a paragraph. His study dealt with four treatments: paragraph only; paragraph and picture without explicit directions to refer to the picture; paragraph and picture with minimal directions to look at the pictures; and paragraph and pictures with directions to study the picture. The 192 third and sixth grade subjects each read three passages. Half of the subjects in each treatment read passages which were assessed as being at the first grade reading level while the other subjects read passages constructed for their grade level. Each of the picture-passage relationships were similar in nature, however, the passages did refer to different topics. After reading each passage, the students were asked to verbally state the main idea of the paragraph. Analysis of the results indicated that the pictures did not enhance the students' ability to state the paragraph's main idea.

In a related study, Koenke and Otto (1969) constructed three paragraphs, each with two illustrations. One of the pictures depicted the main idea of the passage while the other illustrated a specific section of the passage. Two of the paragraphs were assessed as being at the fifth grade reading level while the third paragraph was written at the sixth grade level. Subjects were third and sixth graders from a suburban Wisconsin community. Treatment groups were as follows: passage only; passage and specific content picture; passage and main idea picture. After reading each passage, the students were asked to state the main idea of the paragraph. Analysis indicated that the pictures enhanced the response rating of students who read easy material (sixth graders reading fifth grade level passages), but that the verbal descriptions between the two picture treatment groups were not significantly different. No significant differences were noted for the third graders. This is not surprising as the younger students in all three treatments were reported as having difficulty reading passages above their grade level.

In order to investigate the possible interaction between the subject's level of reading ability and the mode of presentation (picture or printed words) Levin (1973) presented two 12 sentence stories to 54 fourth graders classified by their achievement on a standardized reading test and their teacher's ranking of their classroom reading achievement. One-third of the subjects received two sequences of 12 cartoon-like color drawings (corresponding to each sentence of the printed text). The remainder of the children read the printed stories; half of these subjects also received visual imagery instructions. Thirteen questions concerning the content of each story were then presented. Results indicated that "good" readers scored significantly higher on the comprehension questions than "poor" readers, but that there was not a significant interaction between reading level and mode of presentation. No significant difference in comprehension was noted between the picture and printed story presentations; however, those subjects who received imagery instructions had significantly higher scores than those children who read the passages without imagery instructions.

A later study by Rohwer and Matz (1975) investigated the effect of pictures and print in learning orally presented prose and the influence of socioeconomic status (SES). Three passages, judged to be at a level read by all 128 fourth grade subjects, were orally presented via an audiotape. The subjects simultaneously viewed a sequence of 16 slides presenting either printed sentences or pictures. Each of these slides depicted prior information from the passage plus new information just being revealed in the oral presentation; hence, the final slide presented the total passage in either a printed or a picture form. After each story, the subjects were individually presented with 12 statements to be judged as true or false in terms of the passage. Results indicated that the accompanying picture presentation treatment resulted in higher comprehension scores than the printed presentation. There was also a significant effect due to SES. More interesting was the interrelationship between SES and presentation mode. White subjects ranked as within a high SES averaged approximately 89% correct on comprehension within the picture presentation mode and black subjects ranked as within a low SES averaged about 81% correct. However, within the printed presentation treatment, white subjects ranked with a high SES averaged 82% correct on comprehension whereas black subjects ranked as within a low SES averaged approximately 57% correct--almost at chance level.

One further series of studies has investigated whether the construction of pictures to illustrate a story by children or the observation of the construction of such pictures will facilitate the learning of written passages. Initially 24 first grade subjects individually listened to a reading of five single-episode stories suitable for their grade level. After each reading, half of the students were asked to construct a picture, using plasticized background scenes and cutout objects, to show what happened in the story; control subjects performed an unrelated task after each reading. Each of the subjects was then asked to verbally retell the story. Contrary to expectations, analysis of the verbal statements noted that significantly more propositions (32%) were recalled by the control subjects than by the picture subjects (21%). There was a positive relationship between verbal recall and picture adequacy, i.e.

subjects constructing accurate representations were able to recall at a higher level than subjects who constructed inadequate pictures. However, generally the constructed illustrations were poor as less than half of the pictures conveyed the main idea of the passage.

Hypothesizing that this seeming picture interference was due either to the number of cutouts or to the experimental procedure, which prevented the subjects from constructing their picture until the entire story had been read, Lesgold, Levin, Shimron, and Guttman (Note 3) systematically varied these factors in a follow-up study with 48 first graders. In this study, half of the subjects in the picture treatment constructed an illustration after each sentence of a passage; the remainder of the picture group constructed their illustrations after hearing the entire story. Similarly, the timing of the control tasks varied. Also the children in the picture treatment received only those cutouts necessary to construct an illustration for a given sentence or passage. After hearing three stories and completing the treatment activities, each child was asked to retell the stories, given the titles of the passages as a clue. After recalling a given story, the subject was then asked five short-answer questions, one about each sentence in the story. Analysis of the results indicated that timing had no effect on recall, however, recall was facilitated by the auxillary illustration activity.

In a related experiment, first graders either observed an adult construct pictures after the adult read aloud each sentence of a passage or the first graders constructed their own illustrations. No significant difference in recall was noted between the groups.

These studies indicated that either the number of stories or the amount of cutouts or the need to select cutouts caused the inhibitory effect of pictures within the first experiment.

In order to further understand the picture construction-prose learning relationship, another study was undertaken by the same researchers. Thirty-six first graders were randomly assigned to three conditions: picture construction by child after each story; observation of picture construction by the experimenter after each story; and, control. Background and cutout forms for all three stories were available; hence, the picture construction group had to select appropriate figures as well as construct illustrations. Analysis indicated no significant difference between the groups on free recall responses, but the children in the picture observation treatment scored significantly higher on the short-answer questions than either of the other treatments. A review of the results of this series of experiments indicates that an illustration activity assisted comprehension of written passages for first graders when the choice of items for the illustration was not left to the child.

Pictures and the Solution of Mathematical Word Problems

Problem solving may require a subject not only to conceptualize the interrelationships of the data presented within a problem, but also to represent the problem verbally or visually. Frandsen and Holder (1966) suggested that when problems such as rate of travel are presented verbally, solution depends upon the subject's ability to "hold in his mind" and to manipulate the various components of the problem. Pictures may assist subjects in this effort.

Sherrill (1971) investigated the effects of varying presentations of mathematical word problems upon the problem solving ability of tenth graders. He developed a test using selected mathematics word problems from tenth grade mathematics tests and from the Y- and Z- Population Test Batteries of the National Longitudinal Study of Mathematical Abilities (NLSMA). Three forms of the test were prepared and administered to three samples of tenth graders: (a) written word problems only (114 subjects); (b) written word problems each with an accurate pictorial representation of the problem (96 subjects); and (c) written word problems with inaccurate distorted pictures (112 subjects). Analysis indicated that success in problem solving was affected by the method of presentation as written problems together with accurate pictures led to higher scores than written problems alone, which were superior to written problems in conjunction with distorted pictures. This study also indicated a significant correlation between problem solving ability and IQ, reading ability, and previous grades in mathematics. Inferences concerning the apparent ranking of problem presentations for this sample may not be generalizable to students of differing mathematical aptitude or achievement, due to the strong influence of the affective domain.

A later study by Kulm, Lewis, Omari, and Cook (1973) investigated the relationship between aptitude (as measured by IQ scores) and varying methods of presenting mathematical word problems. Ten problems were selected from algebra and pre-algebra textbooks as representing the various problem-types and levels of difficulty associated with mathematics word problems. These problems were termed the textbook problems. Pictorial versions of these problems were then constructed with minimal verbal content. Six algebra students were given the pictorial versions and asked to construct their own word problems based on the pictures. These versions were termed the student generated problems. Using these three sets of problems, five problem presentations were devised: (a) textbook problems only; (b) student generated problems only; (c) pictorial problems only; (d) textbook problems with accompanying pictures; and (e) student generated problems with accompanying pictures.

Subjects (116 ninth graders enrolled in an algebra class) were randomly assigned to one of the five presentations. Each problem was presented on an overhead transparency for one minute; the students were told to take any notes they needed during that time. The problem was then removed, and the students were allowed three minutes in which to solve the problem before the next problem was projected. Analysis of the data revealed a significant correlation between problem solving ability and IQ. Students within the low IQ group (below 110) were able to discern and use the correct method with textbook type problems significantly more than with any of the three presentations involving pictures. The textbook problem with accompanying picture presentation was significantly less effective than any of the other presentations. No significant effect due to problem presentation was noted for the medium (110-119) and high (above 119) IQ groups in terms of identification and use of a correct method to solve the problems.

In 1960, two Soviet studies investigating the influence of pictures and diagrams on arithmetic problem solving were published. The problems used in these studies are typical of the problems in American first-year algebra textbooks, such as mixture problems or rate problems. However, the Soviet mathematics curriculum includes these problems during the first five or six grades to be solved without the use of algebra.

Botsmanova (1960a) conducted a series of investigations to assess the effectiveness of various forms of pictorial aids on problem solving. Pictures were classified within three forms:

(a) Object-illustrative pictures which portrayed the objects mentioned in the problem, but did not reflect the mathematical structure of the problem.

(b) Object-analytical pictures which portrayed the objects mentioned in the problem and reflected the mathematical structure of the problem.

(c) Abstract spatial diagrams which portrayed numerical relationships.

Botsmanova assumed that if a picture was used in the problem solving process, the student should be able to reproduce or describe the picture after solving the problem. Based on this assumption, she presented 137 students (grades 1-4) with a problem and an accompanying picture telling each student to: "Examine the picture carefully; perhaps it will help you solve the problem" (p. 106). Analysis of the data revealed that many students were able to adequately reproduce the analytic pictures, with a lower percentage of students able to recollect illustrative pictures. Botsmanova interpreted this as meaning that analytic pictures were indirectly used in the problem solving process. A related study by Botsmanova indicated that for most of the second, third, and fourth graders sampled, problems presented with analytic pictures were solved in a shorter time than were problems with illustrative pictures.

A second investigation by Botsmanova (1960b) considered the role of graphic diagrams in problem solving. Twelve third graders were selected as subjects for the study. Four of the subjects had 10 experimental problem solving lessons teaching the use of graphic diagrams over a three month period. Four other subjects also had 10 problem solving sessions, but they were not given graphic diagrams. Rather, they were simply instructed to solve the same problems as the experimental group and to ask questions if they needed help. These students formed the first control group. The remaining four subjects remained in the classroom; they were designated as the second control group.

After the three month treatment, the 12 students were asked to solve three problems. If their solution was incorrect, they were directed to try again until they solved the problem correctly. The first problem was presented without a graphic diagram; however, the students were told: "If you need to, you may draw" (p. 121). The second problem was also presented without a diagram, and no hint was given to construct a graph. The third problem had an accompanying diagram. All of the subjects in the experimental group constructed a graphic diagram for the first two problems; each of these students was able to eventually solve all three problems. None of the students in the control groups were able to solve the first problem despite repeated attempts (142 attempts across the eight subjects). The second problem was solved correctly by five of the control students, and the third problem was solved by four of the control students. Botsmanova interpreted these results as indicating that the use of graphic diagrams was an effective method to teach independent arithmetic problem solving.

The students who participated in these studies were first through fourth graders (approximately 8 to 11 years old), but their mathematics curriculum was not the elementary mathematics curriculum used in the United States. Results of these studies should not be generalized to the teaching of primary school mathematics in America.

Summary

Children respond differently than adults to illustrations and generally obtain less information from them than adults. Children tend to initially perceive discrete items within pictures and gradually develop the ability to relate the depicted characters and to describe the pictures in terms of overt action (Carpenter, 1964; Levie, 1973; Miller, 1938b; Travers & Alvarado, 1970). By the age of 6 or 7, children are able to recognize characters within pictures (Brown & Scott, 1971; Entwisle & Huggins, 1973) and identify whether they are engaged in tasks different from previous drawings, as well as recognizing orientation or location changes (Brown & Campione, 1972; Mandler & Stein, 1974; Stein & Mandler, 1974, 1975). Motion is one of the more difficult representations for children to perceive in static pictures; perception of the dynamic nature of pictures may be dependent on the child's own experience with change and the degree to which the artistic convention or characters depicting motion within the picture are realistic to the child (Friedman & Stevenson, 1975; Schnall, 1968; Travers, 1969). Hence, studies seem to suggest that at age 6 or 7 some children may have developed the potential to relate items within a sequence of pictures and to assimilate them into a single event, particularly if the pictures are simple, realistic, and if the relevant characteristics of the pictures stand out artistically. Picture sequences within Schnall's studies provided further visual clarity by maintaining identical background features throughout the sequence.

Recent studies concerning reading and pictures seem to indicate that pictures may interfere with learning to read, in terms of comprehension and in terms of learning sight vocabulary. Do pictures also interfere with the learning of primary school mathematics? Recent studies dealing with the use of pictures as an aid in independent problem solving of mathematical word problems at the ninth or tenth grade level have yielded contradicting results indicating the influence of mathematical aptitude and achievement. Before initiating a comparison of the teaching of primary mathematics with and without the aid of pictures, it is necessary to identify what characteristics of pictures may assist children in interpreting illustrations in terms of a mathematical relationship. In particular, what types of pictures are perceived by primary school children as dynamic, and how is this perception related to the children's interpretation of the pictures as a mathematical relationship?

Current primary school mathematics textbooks do use pictures in conjunction with written numerals, as a means of communicating mathematical relationships to children. The intention is for the children to make a transfer from the dynamic situation illustrated in the picture to the abstract number sentence accompanying the picture. It is often necessary that the children perceive motion within the pictures in order to interpret within the illustration a mathematical relationship. It is also necessary that the children be able to assimilate the characters depicted in the pictures in order to interpret the association between the characters in terms of a mathematical relationship. The investigator suggests that these research studies, demonstrating the difficulty which young children have interpreting illustrations and perceiving motion in static pictures, indicate a need to investigate the possible relationship between children's perception of the dynamic nature of an illustration and their identification of the mathematical relationship depicted by the illustration.

CHAPTER III

DESCRIPTION OF THE STUDY

The purpose of this study was to investigate whether there is a relationship between first grade children's ability to tell a story about a picture or a sequence of three pictures and their ability to describe the picture(s) by a number sentence. The children's stories were analyzed in terms of the degree to which the stories assimilated the characteristics of the picture(s) and indicated perception of motion. Further, the artistic variables characterizing the pictures were controlled so as to provide information concerning which types of illustration best facilitated interpretation of the pictures and perception of mathematical relationships.

Development of the Materials

Pictures

The first grade mathematics textbooks of seven major elementary mathematics series were selected as being representative of the textbooks currently in use in first grade mathematics classes. The series selected were: the Scott Foresman series, Mathematics Around Us (Bolster, Cox, Gibb, Hansen, Kirkpatrick, Robitaille, Trimble, Vance, Walch & Wisner, 1975); the Houghton Mifflin series, Mathematics for Individual Achievement (Denholm, Hankins, Herrick & Vojtko, 1974); the Houghton Mifflin series, School Mathematics Concepts and Skills (Duncan, Capps, Dolciani Quast & Zweng, 1975); the Addison-Wesley series, Investigating School Mathematics (Eicholz, O'Daffer & Fleenor, 1973); the Silver Burdett series, Silver Burdett Mathematics (LeBlanc, Vogeli, Scott, Grimsley & Barnhart, 1973); the Holt, Rinehart and Winston series, Holt School Mathematics (Nichols, Anderson, Dwight, Flournoy, Kalin, Schluep & Simon, 1974); and the Macmillan series, Macmillan Mathematics Series m (Thoburn, Forbes, Bechtel & Nelson, 1976). From these textbooks, 10 illustrations featuring dynamic pictures were chosen as depicting typical addition or subtraction situations. Five of the selected pictures presented addition situations; five of the pictures depicted subtraction events.

For each of these 10 textbook illustrations, a model line drawing was drafted. These model line drawings depicted personified animals or inanimate objects within a simple setting characteristic of humans. Five of the model drawings portrayed motion through the use of postural cues (i.e. picturing arms or legs of the characters in a state of non-equilibrium); five of the model drawings conveyed motion through conventional artistic cues (i.e. using postural cues as well as clouds of dust or wake lines after the characters). Table 1 indicates the distribution of (a) animal and object characters, (b) addition and subtraction events, and (c) postural and conventional motion cues within the 10 model drawings.

Table 1

Distribution of Characters, Arithmetic Operations, and Motion Cues within the 10 Model Drawings

Characters	Operation	Motion Cue
Apples	Addition	Postural
Buses	Subtraction	Conventional
Ducks	Addition	Conventional
Frogs	Addition	Postural
Crayons	Subtraction	Conventional
Spoons	Addition	Postural
Pelicans	Subtraction	Conventional
Corn	Subtraction	Postural
Turtles	Addition	Conventional
Bears	Subtraction	Postural

Two sequences, each consisting of three 5" x 8" (12.7 cm x 20.32 cm) line drawings, were constructed by a commercial artist using the model drawings as a guide according to detailed specifications given by the investigator. Ten of these sequences portrayed the same animal or object characters as in the model drawings; these were called the stylistic sequences. The other ten sequences portrayed human figures in the same setting and engaged in the same activity as in the stylistic sequences with identical spacing and spatial arrangement of the figures. These sequences were called the realistic sequences. The addition or subtraction situation as well as the type of motion cues was constant within the stylistic and the realistic sequences based upon a single model drawing.

The sequences of pictures depicting addition were in the following form:

Picture A: m characters depicted with a simple background.

Picture B: The same m characters as in Picture A being joined by k other characters. The two groups of characters were disjoint; the group of k characters was pictured with artistic cues to suggest motion toward the group of m characters. The same background as in Picture A was utilized.

Picture C: (m + k) characters pictured in one group. The same background as in Picture A was utilized.

The sequence of pictures depicting subtraction events were in the following form:

Picture A: (i + j) characters in one group depicted with a simple background.

PIcture B: j of the characters in Picture A were pictured as leaving the other i characters. The two groups of characters were disjoint; the group of j characters was pictured with artistic cues to suggest motion away from the group of i characters. The same background as in Picture A was utilized.

Picture C: i characters pictured in one group. The same background as in Picture A was utilized.

The values of m, k, i, and j were selected so that $m,k \leq 5$, $i,j \leq 5$, and $m + k \leq 7$, $i + j \leq 7$. In each sequence, the actual distance between the two disjoint subsets depicted in Picture B was at least 2 inches (5.08 cm).

Each sequence of pictures was assigned a number from 1 to 20. Within each sequence, the initial picture was identified as A, the middle picture as B, and the final picture as C. For example, the pictures in the third sequence were identified as Pictures 3A, 3B, and 3C.

The set of 10 stylistic pictures was assigned the following order:

(a) Sequence of apple pictures (1A, 1B, 1C)
(b) Sequence of bus pictures (2A, 2B, 2C)
(c) Sequence of duck pictures (3A, 3B, 3C)
(d) Sequence of frog pictures (4A, 4B, 4C)
(e) Sequence of crayon pictures (5A, 5B, 5C)

(f) Sequence of spoon pictures (6A, 6B, 6C)

(g) Sequence of pelican pictures (7A, 7B, 7C)

(h) Sequence of corn pictures (8A, 8B, 8C)

(i) Sequence of turtle pictures (9A, 9B, 9C)

(j) Sequence of bear pictures (10A, 10B, 10C).

The corresponding realistic sequences were ordered in the same manner and identified as Pictures 11A, 11B, 11C through 20A, 20B, 20C. For the reduced reproductions of all of the pictures, see appendix A.

The second illustration of each sequence characterized the form of most single dynamic illustrations in the first grade mathematics textbooks examined at the onset of the study. Therefore, these pictures were selected as the single pictures in the study. Those students who were selected to view and describe single pictures in the study saw only Picture B of the sequences. Those students who were selected to view and describe sequences of pictures saw Pictures A, B, and C.

Number Sentence Cards

A set of five number sentence cards (3" x 5") (7.62 cm x 12.7 cm) was made for each of the sequences. One of these number sentences was identified as the intended response for the picture(s); this number sentence was either an addition or subtraction statement in the form $m + k = p$ or $q - j = i$. The other four number sentence cards served as distractors.

Four types of distractor sentences were chosen for pictures portraying addition, and four types of distractor sentences were chosen for pictures portraying subtraction events. These distractor types were identified through related exploratory investigations conducted by PMDC concerning first grade children's interpretations of mathematical events in terms of number sentences.

The actual distractor number sentences for specific addition pictures were selected in the following manner. In each of the addition sequences, Picture B depicted m characters being joined by k other figures from either the left or the right. The intended number sentence was $m + k = p$. If the k characters were pictured joining the m stationary characters from the left, the distractor number sentences were:

(a) $k \quad m$
(b) $m \quad k \quad m \quad p$
(c) $p - k = m$
(d) $p + 0 = p$.

If the k characters were pictured joining the m stationary characters from the right, the distractor number sentences were:

(a) $m \quad k$
(b) $m \quad m \quad k \quad p$
(c) $p - k = m$
(d) $p + 0 = p$.

The actual distractor number sentences for specific subtraction pictures were selected in a similar manner. In each of the subtraction sequences, Picture B depicted j characters leaving the other i stationary characters from either the left or the right. The intended number sentence response was q - j = i. If the j characters were pictured leaving the i stationary characters from the left, the distractor number sentences were:

(a) j i
(b) q j i i
(c) j + i = q
(d) i - j = i.

If the j characters were pictured leaving the i characters from the right, the distractor number sentences were

(a) i j
(b) q i j i
(c) i + j = q
(d) i - j = i.

The order of presentation of each type of distractor sentence and the intended number sentence response was balanced across the 10 sequences. The number sentence cards within each sequence were then assigned an identification letter code (a, b, c, d, or e) in addition to the sequence number. For each item, the first number sentence card was identified as a, the second card as b, and so on with the last number sentence card coded as e. For example, the number sentence cards for the fifteenth sequence were identified by 15a, 15b, 15c, 15d, and 15e.

Response Form

Students' responses during the testing were recorded by the examiners on a response form developed by the investigator (see appendix B). For each item within the test responses were evaluated by the examiner within three categories:

(a) The level of assimilation revealed within the student's verbal story; that is, whether or not the student identified some or all of the subsets depicted in the picture or sequence and whether or not the student related the subsets or pictures.

(b) The verb form used by the student when telling a story to describe the picture; in particular, whether or not the student's story indicated perception of motion by stating action verbs.

(c) The number sentence chosen or written by the student to describe the mathematical relationship depicted in the picture(s).

Description of responses within each category were noted on the response form. During the testing, the examiners checked (✓) the appropriate description of the students' responses.

The Experimental Design

In order to permit an analysis of the effects of the drawing style, realistic versus stylistic, of the number of pictures in an item, sequence of three pictures versus a single picture, and of the response condition, choosing a number sentence (force) versus writing a number sentence (no force), an 8 x 2 design was utilized. Ninety-six first grade subjects were randomly assigned to the 16 cells. Six students composed each cell.

The stylistic treatments were as follows:

S_1: Subjects viewed and described 10 single stylistic line drawings (1B, 2B, 3B through 10B).

S_3: Subjects viewed and described 10 sequences of three stylistic line drawings (1A, 1B, 1C through 10A, 10B, 10C).

S_1S_3: Subjects initially viewed and described five single stylistic line drawings (1B, 2B, 3B through 5B). Then the subjects viewed and described five sequences of three stylistic line drawings (6A, 6B, 6C through 10A, 10B, 10C).

S_3S_1: Subjects initially viewed and described five sequences of three stylistic line drawings (1A, 1B, 1C through 5A, 5B, 5C). Then the subjects viewed and described five single stylistic line drawings (6B, 7B, 8B through 10B).

Similar treatments existed for the realistic drawings (R_1, R_3, R_1R_3, R_3R_1). Each treatment was further characterized by a force (F) or a no force (NF) response condition. Therefore, investigation of each of the eight treatments under two response conditions resulted in 16 cells (Table 2).

Table 2

Experimental Design

	R_1	R_3	R_1R_3	R_3R_1	S_1	S_3	S_1S_3	S_3S_1
F								
NF								

The Research Hypotheses

This study investigated the following research hypotheses:

H_1: There is no difference in first graders' perception of motion in realistic line drawings as compared to stylistic line drawings.

H_2: There is no difference in the level of assimilation revealed in stories told by first graders in response to presentation of realistic line drawings as compared to their responses upon presentation of stylistic line drawings.

H_3: There is no difference in the ability of first graders to state number sentences to characterize the mathematical relationships depicted in realistic line drawings as compared to their number sentence characterizations of stylistic line drawings.

H_4: There is no difference in the ability of first graders to state number sentences to characterize the mathematical relationships depicted in realistic line drawings under a free response condition as compared to a fixed response condition.

H_5: There is no difference in the ability of first graders to state number sentences to characterize the mathematical relationships depicted in stylistic line drawings under a free response condition as compared to a fixed response condition.

H_6: There is no difference in first graders' perception of motion in single line drawings, sequences of three line drawings, or a combination of sequence and single line drawings as indicated by their story responses.

H_7: There is no difference in the level of assimilation revealed in stories told by first graders in response to presentation of single line drawings, of sequences of three line drawings, or of a combination of sequence and single line drawings.

H_8: There is no difference in the ability of first graders to state number sentences to characterize the mathematical relationships depicted in sequences of three line drawings as compared to their number sentence characterizations of single line drawings or combinations of single and sequence line drawings.

H_9: Viewing and describing a sequence of three line drawings does not provide a learning experience to assist first graders in perceiving motion within single line drawings, as indicated by their story responses.

H_{10}: Viewing and describing a sequence of three line drawings does not provide a learning experience for first graders as evidenced by the level of assimilation revealed in their stories upon presentation of single line drawings.

H_{11}: Viewing and describing a sequence of three line drawings does not provide a learning experience to assist first graders in stating number sentences to characterize the mathematical relationships depicted in single line drawings.

H_{12}: There is no correlation between the ability of first graders to perceive motion within two-dimensional line drawings and their ability to state, as number sentences, the mathematical relationships depicted by the drawings.

H_{13}: There is no correlation between the ability of first graders to tell stories to describe line drawings and their ability to state, as number sentences, the mathematical relationships depicted by the drawings.

H_{14}: There is no correlation between the ability of first graders to state, as number sentences, the mathematical relationships depicted by line drawings and their level of mathematical achievement as measured by the Key Math test.

Subjects

The subjects for this study were randomly selected from three first grade classes at Pineview Elementary School and from two first grade classes at the Developmental Research School. Pineview Elementary School is one of several public elementary schools in Tallahassee, Florida. The Developmental Research School is the university laboratory school affiliated with the College of Education of The Florida State University.

The Key Math test (a standardized, individualized mathematics achievement test) was administered to each student in the five first grade classes at the beginning of the school year. At the time of the study, 122 of these students were available. Seven of these students were subjects of another investigation and were therefore not eligible for this study. From the remaining 115 students, 96 subjects were selected and assigned to an experimental treatment (e.g. R_3 force) by means of a random numbers table (Remington & Schork, 1970, pp. 358-361). Forty-one of the selected students were enrolled at the Developmental Research School and had an average entering Key Math score of 46 (first grade, fifth month grade equivalent). The remaining 55 students were enrolled at Pineview Elementary School and had an average entering Key Math score of 38 (first grade, second month grade equivalent).

The students at the Developmental Research School used the Houghton Mifflin series Mathematics for Individual Achievement. At the time of the study these students were reviewing the basic facts (addition and subtraction) through sum 10 and identifying, from a collection of facts, those addition or subtraction facts which had the same solution. The students at Pineview Elementary School used either the Houghton Mifflin series Mathematics for Individual Achievement or the Holt, Rinehart, and Winston series Holt School Mathematics. Those students using the Houghton Mifflin series were studying the basic facts (addition and subtraction) through sum 9, while the students using the Holt series were studying related addition and subtraction facts through sum 10.

Procedure

The testing instrument was individually administered to each student by one of four examiners during the week of February 23-27, 1976. All four of the examiners had previous experience testing first grade children in an individual setting. Prior to the testing, the examiners received an examiner's manual (see appendix C) and attended a training session. At this session, the examiners viewed videotape recordings of the pilot administration of the testing instrument and evaluated the recorded student responses.

During the administration of the test, each examiner was permitted to offer reassurances to the student by the following means:

(a) repeating the student's response.

(b) murmuring "Okay," "Fine," or "Alright."

(c) smiling or nodding.

The examiner was permitted to repeat questions but not to rephrase questions. If a student gave an incomplete response, the examiner probed by asking the student, "Tell me more." If a student did not respond to a question within 15 seconds, the examiner repeated the question. If the student still did not respond, the examiner went on to the next question. Each student was told by the examiner that they were going to look at some pictures and that the examiner would be asking some questions about the pictures. The examiner did not refer to the pictures as either a test or a game.

The test was administered to each student in the following manner.

After attempting to put the student at ease, the examiner placed either a single picture (B) or a sequence of pictures (A, B, C) horizontally before the student. The student was then told that the picture(s) told a story and he(she) was requested to tell a story to go with the picture(s). The examiner then checked (✓) the appropriate description of the student's story on the response form and noted whether or not the story indicated perception of motion.

Then, for students in the force response condition, the examiner placed five number sentence cards horizontally between the student and the picture(s) in a predetermined order. The student was requested to choose the number sentence that described the picture(s). The student's response was recorded by the examiner on the response form.

A student in the no force response condition did not see any number sentence cards, rather, after telling a story to describe the picture(s), he(she) was given a pencil and a blank sheet of paper. The student was then requested to write a number sentence to describe the picture(s). The student's response was recorded by the examiner on the response form.

This procedure was repeated for each of the 10 items presented to each child. The average student completed the test in 15 minutes.

All testing was audio-tape recorded. Upon completion of the testing of the 96 subjects, these tapes were used to verify the examiner's response descriptions noted on the response forms prior to scoring.

Selected story responses representative of the stories told by the students in this study are presented in appendix D, as well as the level of assimilation and the score assigned to those story responses.

CHAPTER IV

RESULTS

Statistical Treatment of the Data

For each item, two initial responses were obtained from each student: a verbal story to describe the pictured event and a number sentence to characterize the mathematical relationship depicted in the picture(s). Each story was also classified as to whether or not it indicated perception of motion, yielding a third response category. This resulted in three sets of data which were analyzed in terms of the research hypotheses stated in chapter three (H_1 through H_{14}).

Initially each response was assigned either a 0 (unacceptable) or a 1 (acceptable). Summing these response scores over the 10 items, each student had three total scores: story response (0-10), perception of motion (0-10), and number sentence response (0-10). This procedure yielded scores scattered throughout the range from 0 to 10 and a large percentage of scores at 0 and 10. Thus, the assumptions necessary for analysis of variance were not satisfied. Due to the number of ties resulting from the small range of possible scores, nonparametric statistical methods could not be used. Therefore, a scoring procedure was defined to assign a score to story and number sentence responses which revealed specific levels of understanding as defined for this study.

In order to characterize levels of understanding for the number sentence tasks in this study, behaviors were identified which composed a correct number sentence response. The number sentence responses of the students were then evaluated in terms of the number of identified behaviors which the response revealed. For each identified behavior revealed in a response one point was assigned. The behaviors identified as composing the correct number sentence responses were:

(a) Identification of one set per picture or of one set for the entire sequence.

(b) Identification of each disjoint set depicted within a picture.

(c) Identification of a total set inferring recognition of the two subsets making up the total set.

(d) Identification of an operation between the disjoint sets.

If the observed number sentence response did not demonstrate any of the identified behaviors, a score of 0 was assigned. Using this procedure, each number sentence response was assigned a score from 0 to 4 (see appendix E).

The levels of understanding for number sentence tasks in this study were thus defined in terms of the number of identified behaviors which a response indicated. Although it was possible for differing number sentence responses to obtain the same score, this occurred only if the responses revealed the same number of identified behaviors and, therefore, the same level of understanding as defined for this study.

Similarly, in order to characterize levels of understanding indicated in the story responses, behaviors were identified which composed a correct story response. The story responses of the students were then evaluated in terms of the number of identified behaviors which the response revealed. For each identified behavior revealed in a story response, one point was assigned. The behaviors identified as composing the correct story responses were:

(a) Identification of one set per picture or of one set for the entire sequence.

(b) Identification of each disjoint set depicted within a picture.

(c) Identification or indication of a total set formed by the relationship of the two subsets.

(d) Identification of motion.

If the observed story response did not demonstrate any of the identified behaviors, a score of 0 was assigned. Using this procedure, each story response was assigned a score from 0 to 4 (see appendix F).

The levels of understanding for story description tasks in this study were thus defined in terms of the number of identified behaviors which a response indicated. Although it was possible for differing story responses to obtain the same score, this occurred only if the responses revealed the same number of identified behaviors and, therefore, the same level of understanding as defined for this study.

Using this scoring procedure and summing the scores over the 10 items, each student had three total scores: a characterization of the level of assimilation revealed in his stories (0-40), a characterization of his overall perception of motion (0-10), and a characterization of his number sentence responses (0-40) (see appendix G). This scoring procedure yielded response and number sentence scores which were scattered throughout the range from 0 to 40. This indicated possible violation of the assumption of normality as required for analysis of variance procedures. Therefore, the data were analyzed by use of the Kruskal-Wallis test (a nonparametric, distribution-free analysis of variance) and the Mann-Whitney U test (a nonparametric, distribution-free rank test).

Realistic versus Stylistic Drawing Style

The first three research hypotheses (H_1, H_2, and H_3) consider the treatment effect of drawing style (realistic versus stylistic) on (a) the students' perception of motion, as indicated by their story responses, (b) the level of assimilation revealed in the students' story responses, and (c) the students' characterization of the mathematical relationships depicted in the drawings by number sentences.

With τ_1 defined as the (unknown) treatment effect of viewing realistic line drawings and τ_2 as the (unknown) treatment effect of viewing stylistic line drawings, the null hypothesis:

$$H_o: \tau_1 = \tau_2$$

was tested against the alternative hypothesis that $\tau_1 \neq \tau_2$ on each of the three sets of data (motion perception scores, story response scores, and number sentence scores).

The observed Kruskal-Wallis $\underline{H}$ statistic was calculated for each of the three sets of data. Based upon the motion perception scores, $\underline{H} = .4844$; based upon the story response scores, $\underline{H} = .1119$; and, based upon the number sentence scores, $\underline{H} = .0534$.

Due to the large size of the sample for this investigation ($\underline{n}_1 = \underline{n}_2 = 48$), the critical value was determined by the χ^2 distribution (Hollander & Wolfe, 1973, p. 115). The critical value for this two-sided test with $\alpha = .05$ is 3.841.

Since the observed value of $\underline{H}$ is less than the critical value in all three cases, the null hypothesis cannot be rejected at the .05 level. That is, the drawing style (realistic versus stylistic) did not have a significant effect on either the overall perception of motion, on the level of assimilation within descriptive stories, or on the number sentence responses given by first graders in this study.

The data used for the Kruskal-Wallis tests were the three total scores for each student; no criteria concerning consistency of responses to the 10 similar items were applied in the scoring. Thus, a follow-up Chi-square analysis was conducted using only the scores of subjects who responded consistently for 7 or more of the 10 items. Table 3 gives the contingency table for students who consistently told similar verbal stories. Subjects were classified as assimilators if they told seven or more stories which not only identified both addends, but also related the addends in a manner suggesting perception of motion. Subjects were classified as enumerators if they told seven or more stories which identified both addends, but failed to relate the addends as a whole.

The critical value for a .05 level test is 3.841 and the observed value for these data is .1877. Therefore, this study indicated that there is no significant relationship between the level of assimilation consistently revealed in stories describing pictured events and the drawing style (realistic or stylistic) used to depict the event.

Table 3

Contingency Table Indicating Students who Consistently Told Similar Stories for Realistic or Stylistic Drawings

Verbal Stories	Realistic Drawings	Stylistic Drawings	Total
≥ 7 Assimilated	24	24	48
≥ 7 Enumerated	9	7	16
Total	33	31	64

Force versus No Force Response Mode

The effect of the response condition (force versus no force) on the students' ability to state a number sentence, characterizing the mathematical relationship depicted in the pictures, is considered in research hypotheses H_4 and H_5. τ_{RF} was defined as the (unknown) treatment effect of viewing realistic pictures and choosing a number sentence response (force) and τ_{RN} was defined as the (unknown) treatment effect of viewing realistic pictures and writing a number sentence response (no force). Similarly, τ_{SF} and τ_{SN} were defined as the (unknown) treatment effect of choosing and writing number sentences to characterize mathematical relationships depicted in stylistic pictures. The research hypotheses H_4 and H_5 may be characterized by the null hypotheses:

$$H_{04}: \tau_{RF} = \tau_{RN}$$

$$H_{05}: \tau_{SF} = \tau_{SN}$$

These null hypotheses were tested against the alternatives $\tau_{RF} > \tau_{RN}$ and $\tau_{SF} > \tau_{SN}$ respectively at $\alpha = .05$, using the number sentence scores.

Due to the large size of the sample ($\underline{n}_{RF} = \underline{n}_{RN} = \underline{n}_{SF} = \underline{n}_{SN} = 24$), the Mann-Whitney U statistic was adjusted (Siegel, 1956, p. 121) by:

$$\underline{z} = \frac{\underline{U} - (\underline{n}_1)(\underline{n}_2)}{\sqrt{\dfrac{(\underline{n}_1)(\underline{n}_2)(\underline{n}_1 + \underline{n}_2 + 1)}{12}}}$$

where $\underline{n}_1$ and $\underline{n}_2$ denote the sample size. The critical value for a one-sided test with $\alpha = .05$ is -1.645. Based upon the number sentence scores of students who viewed realistic pictures, the observed adjusted statistic $\underline{z} = -3.623$ and, for students who viewed stylistic pictures, $\underline{z} = -3.2007$.

Since the observed value of $\underline{z}$ is less than the critical value $\underline{z}_{.05}$ for both tests, the null hypotheses H_{04} and H_{05} are rejected ($\underline{p} = .00015$ and $\underline{p} = .0007$ respectively). This means that in this study students who chose number sentences to characterize the mathematical relationships depicted in the pictures, whether realistic or stylistic, performed significantly better than those students who wrote number sentences.

In a post-study analysis, the story responses of students who chose number sentences were compared with the story responses of students who wrote their own number sentences to characterize the pictures. This was done in order to assess whether the manner by which a student gave a number sentence response to a given item influenced his story response to a succeeding item. Since an underlying assumption of this study was that each student responded to each item independently and under equivalent conditions, it was necessary to assume that such an influence did not occur.

With τ_F defined to be the (unknown) treatment effect of choosing a number sentence and τ_N to be the (unknown) treatment effect of constructing a number sentence, the null hypothesis:

$$H_o: \quad \tau_F = \tau_N$$

was tested against the alternative $\tau_F \neq \tau_N$ using story response scores.

The observed Kruskal-Wallis statistic $\underline{H} = 1.4624$ and the critical level for a .05-level test is 3.841. Therefore, these data support the contention that the response mode for number sentences had no effect on subsequent verbal story responses.

Single versus Sequence Pictures

The next six research hypotheses (H_6 through H_{11}) consider the influence of depicting an event by a sequence of three pictures or by a single picture upon (a) the students' perception of motion, (b) the level of assimilation revealed in the students' stories, and (c) the students' characterization of the event by a number sentence. The three sets of data were initially analyzed utilizing responses from all students. Then, in order to consider the potential learning experience of viewing and describing sequences prior to viewing single pictures (H_9, H_{10}, and H_{11}), subsets of each of the three data collections were again analyzed. In order to maintain an overall α of .05, the α for these analyses was set at the .025 level.

τ_1 was defined as the (unknown) treatment effect of viewing only single pictures and τ_2 was defined as the (unknown) treatment effect of viewing only sequences of three pictures. τ_3 was defined as the (unknown) treatment effect of initially viewing and describing five sequences and then viewing five single pictures, whereas τ_4 was defined as the (unknown) treatment effect of viewing five single pictures followed by five sequences. The null hypothesis:

$$H_0: \tau_1 = \tau_2 = \tau_3 = \tau_4$$

was tested against the alternative hypothesis:

$$H_A: \tau_i \neq \tau_j \text{ for some } i,j = 1, 2, 3, 4$$

on each of the three sets of data (motion perception scores, story response scores, and number sentence scores).

The observed Kruskal-Wallis $\underline{H}$ statistic was calculated for each of the three sets of data. As determined by the motion perception scores, $\underline{H} = 5.1827$; based upon the story response scores, $\underline{H} = 7.1651$; and, based upon the number sentence scores, $\underline{H} = 1.067$.

The critical value with $\alpha = .025$ is 9.348. Since the observed values of $\underline{H}$ are less than the critical value, the null hypothesis cannot be rejected at the .025 level as determined by any of the complete data sets. Hence, no significant differences in motion perception, assimilation level, or number sentence responses were noted between students who viewed single pictures, sequences of pictures, or a combination of single and sequence pictures.

It was noted that whereas $\underline{p} = .1589$ and $\underline{p} = .7851$, as calculated for the motion perception scores and the number sentence scores respectively, $\underline{p} = .0668$ for the story response scores. Therefore, a subsequent Chi-square analysis was performed using only the responses of students who consistently (≥ 7) told stories that were classified as displaying enumeration or as displaying a high level of assimilation. Table 4 shows the contingency table for such students. Only those students who viewed 10 single pictures or 10 sequences were tallied ($\underline{n} = 48$).

The critical value for $\alpha = .05$ is:

Table 4

Contingency Table Indicating Students who Consistently Told Similar Stories for Single or Sequence Drawings

Verbal Stories	Single Drawings	Sequence Drawings	Total
≥ 7 Assimilated	7	16	23
≥ 7 Enumerated	7	2	9
Total	14	18	32

$$\chi^2_{.95} = 3.841$$

and the observed value is:

$$\chi^2 = 5.1014 \text{ (Yates corrected } \chi^2 = 4.1249\text{)}.$$

Since the observed value exceeds the critical value, these data indicate that there was an association between the level of assimilation consistently revealed in stories describing pictured events and the number of pictures (sequence or single) used to depict the event.

In order to determine whether viewing and describing sequences of three related pictures provided a learning experience for single pictures, the responses of students who only saw and described single pictures were compared to the responses of students who initially saw and described five sequences of three pictures and then, saw and described five single pictures. Only the responses to the last five items were compared as, on these items, the students were all viewing single pictures. This analysis was completed on each of the three sets of data (motion perception scores, story response scores, and number sentence scores).

With τ_1 defined as the (unknown) treatment effect of viewing and describing only single pictures and τ_2 as the (unknown) treatment effect of viewing and describing sequences of three pictures prior to viewing and describing single pictures, the null hypothesis:

$$H_0: \tau_1 = \tau_2$$

was tested against the alternative hypothesis:

$$H_A: \tau_1 < \tau_2$$

for each of the three sets of data. Hence, these analyses were one-sided tests with $\alpha = .025$.

The adjusted observed Mann-Whitney U statistic for motion perception scores is $\underline{z} = 2.0233$, for story response scores $\underline{z} = 2.316$, and based upon number sentence scores, $\underline{z} = -.6315$. The .025 critical value for a one-sided test is 1.96.

Based upon motion perception and story response scores the observed value of $\underline{z}$ is greater than the critical value; hence, the null hypothesis was rejected. That is, the observed data indicated that viewing and describing sequences of three pictures prior to viewing single pictures provided a learning experience which resulted in a significantly better perception of motion within the single pictures (p = .0215). Also students who initially viewed and described sequences of pictures told stories to describe single pictures that reflected a significantly higher level of assimilation than those stories told by subjects who viewed only single pictures (p = .0103). Based upon the observed number sentence response scores, the observed value of z is less than the critical value; therefore, the null hypothesis is not rejected at the .025 level. That is, the data provided no evidence to indicate that viewing and describing sequences of three pictures assisted first graders in stating the mathematical relationships depicted in single pictures as number sentences.

Correlations

The possible correlations between first graders' interpretations of pictures (as indicated by their story response scores and motion perception scores) and their subsequent characterization, as number sentences, of the mathematical relationship depicted in the pictures are considered in the next two research hypotheses (H_{12} and H_{13}). The possible correlation between first graders' mathematical achievement, as measured by the Key Math test, and their ability to state number sentences to characterize the mathematical relationship depicted in the pictures is considered in the last research hypothesis (H_{14}).

Scattergrams were constructed for the following comparisons: motion perception scores with number sentence scores; story response scores with number sentence scores; Key Math scores with number sentence scores. Examination of these scattergrams revealed no trend toward a rectilinear relationship between the variables; that is, the scattergrams were not elliptical. Since this indicated that the assumptions required for the Pearson correlation coefficient may not be satisfied, Kendall correlation coefficients were computed (a nonparametric, distribution free correlation test).

The Kendall correlation coefficient between motion perception scores and number sentence scores is .1685. The Kendall correlation coefficient between story response scores and number sentence scores is .2893 and, between Key Math scores and number sentence scores is .2124. Each of these correlations indicates a significant deviation from a population correlation of zero with $p < .01$; however, the large size of the sample ($\underline{n} = 96$) has exerted a strong influence on the determination of the significance. In light of the size of the correlation coefficients, the data obtained in this study do not indicate an educationally significant correlation between number sentence scores and either story response scores, motion perception scores, or Key Math scores.

In an attempt to further examine the possibility of a non-linear relationship between the ability to describe pictures by a story and the ability to characterize the picture by a number sentence, the story response scores and the number sentence scores were ranked. The 14 students with the highest story response scores were identified, as were the 14 students with the highest number sentence scores. A similar identification was made of the 14 students who had the lowest story response scores and of the 14 students with the lowest number sentence scores. The mean Key Math score and the mean and median number sentence and story response scores were computed for each of these four groups of students. These statistics are presented in Table 5.

Examination of Table 5 indicates that, in this study, first graders who were very successful when describing pictures by stories were able to characterize the pictures by a number sentence with some degree of success. Students who demonstrated a high level of achievement in characterizing pictures by number sentences also were very successful in making up stories to describe the pictures. Those students who were not able to describe the pictures were also unable to adequately characterize the pictures by a number sentence. However, most of the students who demonstrated little, if any, ability to state number sentences to characterize the pictures were able to describe the pictures with success. Hence, the data obtained in this

Table 5

Mean and Median Number of Correct Responses by Children Ranked in High and Low Number Sentence and Story Response Groups

	Key Math Scores	Number Sentences		Story Responses	
	Mean[a]	Mean	Median	Mean	Median
Story Responses					
High	49 (1.6)	31	30	40	40
Low	34 (1.0)	14	14	15	16.5
Number Sentences					
High	51 (1.7)	37.5	37	37	39
Low	35 (1.0)	2	1	30	29.5

[a] Numbers in parentheses indicate equivalent grade and month mathematics achievement for the entering Key Math score.

study do not indicate a cause and effect relationship or a linear correlation between the ability to assimilate characteristics of pictures when verbally describing the pictures and the ability to characterize the picture by a number sentence. However, the data do suggest that students who were unable to tell stories which indicated an adequate level of assimilation were also unable to characterize the pictures by a number sentence.

Post-Study Analysis

After completion of the analysis pertaining to the research hypotheses, some further statistical analysis was undertaken in order to further identify potential variables in the study. These variables related to the composition of the pictures and the use of four examiners to administer the testing instrument.

A Kruskal-Wallis test was used to determine what, if any, effect the use of four examiners had upon the collection of data. With τ_i defined as the (unknown) treatment effect of examiner i (i = 1, 2, 3, 4), the null hypothesis:

$$H_0: \tau_1 = \tau_2 = \tau_3 = \tau_4$$

was tested against the alternative:

$$H_A: \tau_i \neq \tau_j \text{ for some } i,j = 1, 2, 3, 4$$

using each of the three sets of data (motion perception scores, story response scores and number sentence scores).

The observed Kruskal-Wallis statistic for the motion perception scores is 4.6406; for the story response scores, $\underline{H} = 4.9638$; and, based upon the number sentence scores, $\underline{H} = 1.3165$. The critical level for a .05-level test is 7.82. Therefore, since each of the observed statistics is less than the critical value, the null hypothesis is accepted for each set of data. That is, the data support the contention that, for this study, the use of four different examiners did not affect the results.

Pictures used in current primary mathematics textbooks portray both addition and subtraction events through a variety of artistic cues. This diversity was reflected in the items selected for the testing instrument. Of the 10 items in the testing instrument, five presented addition situations and five involved subtraction situations. All of the items conveyed motion through artistic cues. Five of the items portrayed motion solely through the use of postural cues (i.e. picturing arms and legs in the state of non-equilibrium); the remaining five items conveyed motion through conventional artistic cues (i.e. using postural cues along with wake lines or clouds of dust after the figure). In order to determine whether the students reacted differently to (a) addition and subtraction portrayal and to (b) postural and conventional motion cues, the Wilcoxon matched-pairs signed-ranks test was used.

For this test, each student's total score on the addition items and on the subtraction items (also on the postural and conventional motion cue items) was computed for each of the three sets of data. The absolute value of the difference of these scores for each student was determined and the nonzero differences were ranked. The statistic ($\underline{T}^*$) was computed from the ranks taking into consideration whether the original difference was negative or positive (Hollander & Wolfe, 1973, pp. 27-28). Students who had a difference score of 0 were dropped from the analysis. Hence this test not only utilized information about the direction of the differences within the pairs, but also the magnitude of the differences.

Table 6 indicates the number of children who reacted differently to addition and subtraction items and the number of children who reacted differently to postural and conventional motion cue items. Table 6 also indicates whether the differences were positive or negative.

Table 6

Frequency Distribution on Positive and Negative Differences between Addition and Subtraction Items and between Items Using Postural Cues and Conventional Cues to Portray Motion

Differences	Motion Perception Scores	Story Response Scores	Number Sentence Scores
Addition Total minus Subtraction Total			
Positive	7	28	26
Negative	30	31	35
Postural Total minus Conventional Total			
Positive	10	24	24
Negative	22	38	38

Of the 96 students, 61 received number sentence scores for addition events that differed from their number sentence scores for subtraction situations (almost 2/3 of the sample). Fifty-nine (out of 96) students also received story response scores on the addition items that differed from their scores on the subtraction items, but only 37 students had motion perception scores for addition items that differed from their motion perception scores for subtraction items.

The observed $\underline{T}^*$ statistic based upon the motion perception scores is -4.0884; as determined by story response scores, $\underline{T}^* = -1.0718$; and based upon number sentence scores, $\underline{T}^* = -.7075$. Due to the large size of the sample, the critical value was determined from the normal distribution. For a two-sided test with $\alpha = .05$, $\underline{z} = -1.96$.

Based upon story response scores and number sentence scores, the observed value of $\underline{T}^*$ is greater than the critical level. This indicated that although some of the students in the study received different number sentence scores or story response scores on the addition and subtraction items, the difference was not significant at the .05 level. However, as determined by the motion perception scores, 37 students (out of 96) perceived motion on the addition items in a manner significantly different from their perception of motion in subtraction items (negative rank sum = 622.5; positive rank sum = 80.5).

Of the 96 students, 62 had number sentence scores for pictures utilizing only postural motion cues that differed from their number sentence scores for pictures involving conventional motion cues. Sixty-two students also received story response scores on the postural motion cue items that differed from their scores on conventional motion cue items (almost 2/3 of the sample). But, only 32 students (1/3 of the sample) received differing motion perception scores.

The observed $\underline{T}^*$ statistic based upon motion perception scores is -2.3093; based upon story response scores, $\underline{T}^* = -2.4293$; and, $\underline{T}^* = -2.0227$, as determined by the number sentence scores. Hence:

$$\underline{T}^* \quad -1.96 = \underline{z}_{.05}$$

for each of the three sets of data.

Therefore, as indicated by this study, for students who had scores for pictures utilizing postural motion cues which differed from their scores for items portraying conventional motion cues, the difference was significant in terms of motion perception scores ($\underline{p} = .0209$), story response scores ($\underline{p} = .0151$), and number sentence scores ($\underline{p} = .0431$).

CHAPTER V

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

This study was designed to consider the role of pictures in first grade children's perception of mathematical relationships. In particular, the purpose of this study was to determine whether there is a relationship between the children's ability to tell a story about a picture or sequence of three pictures and their ability to describe the picture(s) by a number sentence. The artistic variables characterizing the pictures were controlled in order to provide information concerning the influence of these variables on the children's ability to interpret the pictures and to perceive mathematical relationships.

Summary and Implications

Two similar sequences of pictures were drafted for each of the 10 items making up the testing instrument. One of these sequences was termed the realistic sequence and depicted child-like figures within simple settings characteristic of humans. The other sequence was termed the stylistic sequence and depicted personified animals or inanimate objects within the same setting and engaged in the same activity as those in the realistic sequences. The size of each picture was 5" x 8" (12.7 cm x 20.32 cm). The students viewed either sequences of three pictures or a single picture which was obtained by using only the middle picture of each of the three-picture sequences.

In order to permit an analysis of the effects of the form of the drawing, realistic versus stylistic, of the number of pictures in an item, sequence of three pictures versus a single picture, and of the response condition, choosing a number sentence (force) versus writing a number sentence (no force), an 8 x 2 design was utilized.

Ninety-six first graders, randomly selected from five first grade classes within two elementary schools in Tallahassee, Florida, were randomly assigned to each of the 16 cells. Six students composed each cell. Each student was tested individually by one of four examiners. Upon presentation of a single picture or a sequence of three pictures, the child was requested to tell a story to go with the picture(s). The student was then asked either to choose a number sentence card or to write a number sentence for the picture(s). This procedure was repeated for each of the 10 items presented to the child. All testing was audio-tape recorded.

Statistical analysis revealed that the drawing style (realistic versus stylistic) did not have a significant effect ($\alpha = .05$) on either the level of assimilation within the stories, the perception of motion, or the number sentence responses. The first graders in this study seemed to interpret stylistic pictures of personified animals or objects with an ease equivalent to their interpretation of realistic pictures of children. The students constructed stories about, for example, frogs playing marbles or crayons taking a nap with a naturalness comparable to their construction of stories about children playing marbles or napping. The artificial nature of these stylistic stories and pictures did not effect the children's characterizations of the pictures by a number sentence. It is suggested that use of both types of illustrations within primary school mathematics textbooks may provide variety without adversely affecting understanding.

Analysis of the effect of the response condition (force versus no force) revealed a significant difference ($\alpha = .05$) favoring the force condition on number sentence responses. This means that the students in this study who chose number sentences to characterize the mathematical relationships depicted in the pictures, whether realistic or stylistic, performed significantly better than those students who wrote number sentences.

Most of the incorrect responses offered by the students who wrote number sentences were noted among the distractor number sentences provided for the children in the force condition. There was one exception to this. Of the

48 students in the no force response condition, 14 students (29%) wrote the total number of characters depicted in the picture(s) as the number sentence for at least two of the items within the test. These children seemed to view the direction to write a number sentence as an instruction to count the characters for at least two items. It is not known whether this was due to a complete unfamiliarity with the term "number sentence" or to an erroneous definition of the term. The children may not have known what number sentence meant and, in response to a direction to write, they may have simply counted, writing the total. On the other hand, the children may have believed that number sentence involved determining "how many" and, therefore, they wrote the total. Since the children were not asked to explain their number sentence responses, it is not possible to determine the children's reasoning. However, some of the children did not seem at ease with the term "number sentence."

The number of pictures in each item (single, sequence, or a combination of single and sequence pictures) did not have a significant effect on either the level of assimilation revealed within the stories, the perception of motion, or the number sentence responses. Due to the *p* value noted for the story response scores, a subsequent Chi-square analysis was performed using only the story responses of students who viewed either 10 single pictures or 10 sequences and who consistently (≥ 7) told stories classified as displaying enumeration or as displaying a high level of assimilation. This analysis indicated an association between the level of assimilation consistently revealed in stories describing pictured events and the number of pictures (single or sequence of three pictures) used to depict the event.

In order to determine whether viewing and describing sequences of three pictures provided a learning experience for single pictures, responses of students in the sequence-single treatment and the single treatment were compared. Only the responses to the last five items were compared as, on these items, the students were all viewing single pictures. No significant difference was noted between the number sentence scores of students who viewed and described sequences prior to viewing single pictures and the number sentence scores of students who saw only single pictures. However, the analysis did indicate that viewing and describing sequences provided a learning experience which resulted in a significantly better perception of motion and a significantly higher level of assimilation within stories for single pictures. Since the viewing of sequences did have a positive effect on the interpretation of single pictures, it is suggested that sequences of illustrations should be presented within primary mathematics textbooks and that they should be presented prior to single pictures.

No evidence of an educationally significant correlation between number sentence scores and either story response scores, motion perception scores, or Key Math scores was noted. However, the data obtained in this study did suggest that students who were unable to tell stories which revealed an adequate level of assimilation of the characteristics of the pictures were also unable to characterize the pictures by a number sentence. It is suggested that prior to lessons requiring first graders to write or select number sentences for pictures or to write the solutions for number sentences accompanying dynamic illustrations in mathematics textbooks, teachers should first determine if the students are able to interpret the pictures. In particular, the teachers should ascertain whether or not the students can identify both disjoint sets and can recognize a relationship between the disjoint sets which indicates perception of a total set. The number sentence can be a formal recording of the activity depicted in the pictures only if the students understand the pictures. The illustrations may then serve to assist the children in acquiring an understanding of the concepts of addition and subtraction.

Recommendations

This study investigated the effect of two drawing styles, of the number of pictures, and of the response condition on children's interpretations of dynamic illustrations of mathematical relationships. During the drafting of the pictures, other artistic variables which may have an effect on interpretation became evident; namely, placement of characters, spacing, detail, and depth perception. Since these artistic cues were not the focus of this study, all of the illustrations within this study utilized a particular format regarding these variables.

Research studies should be conducted to investigate the influence of these artistic variables. In particular, the addition items within this study depicted one stationary set being joined by the elements of a second set; however, addition may also be depicted as the union of two "moving" sets. Do children in the primary grades perceive these two pictorial interpretations of addition in the same manner or is one form more easily understood? All of the characters in the illustrations in this study were depicted with minimal use of three-dimensional cues. What is the influence of these cues on first, second, and third graders' ability to interpret pictures depicting mathematical relationships? None of the pictures in this study employed either color or shading cues to enhance detail. Although pictures employing these cues may be preferred by children, do these cues effect the children's ability to perceive the mathematical relationships within the pictures?

Current primary school mathematics textbooks seem to emphasize two artistic forms within their illustrations.

One form presents pictures which "tell a story" and which may evoke a dynamic interpretation of addition or subtraction events. These illustrations typically portray groups of human figures or personified characters engaged in motion toward or away from each other. This is the artistic form represented in all of the pictures used in this study. The second artistic form is more static in nature, encouraging counting, and may rely on artistic conventions such as x'ed out items, arrows, or ovals to suggest addition or subtraction. Typically the pictured items are inanimate objects or animals. The results of this study cannot be generalized to static illustrations; rather, further research may investigate the role of static pictures in first and second grade children's perception of mathematical relationships. In particular, how do young children interpret the static artistic conventions? Dynamic pictures suggest stories which represent either addition or subtraction situations; static pictures do not suggest stories but present a more abstract representation of addition or subtraction. Are either dynamic pictures or static pictures more difficult for young children to interpret?

The 10 items in the testing instrument used in this study conveyed motion through two types of artistic cues. Five of the items portrayed motion solely by the use of postural cues (i.e. picturing arms and legs in the state of non-equilibrium); the remaining five items conveyed motion through conventional cues (i.e. using postural cues along with wake lines or clouds of dust after the figures). Statistical analysis revealed that 62 students in this study (out of 96 students) had number sentence scores and story response scores for items utilizing postural motion cues that differed significantly from their number sentence scores and story response scores for items utilizing conventional motion cues. Also 32 students had significantly different motion perception scores on the items portraying motion by conventional cues than on the items utilizing postural cues. These analyses were conducted to identify potential variables in this study and did not pertain to the research hypotheses under investigation. However, the indicated differences in these children's interpretations of these artistic motion cues suggest the need of research studies designed to investigate children's interpretations of postural motion cues and conventional motion cues within mathematical pictures and the influence of these cues on the children's perception of the mathematical relationships portrayed in the pictures. Further investigation may also include pictures of figures without legs which utilize clouds of dust or wake lines as motion cues without additional postural cues (e.g. automobiles, birds).

The results of this study did not indicate a significant difference between the treatments utilizing single pictures, sequences of pictures, or a combination of single and sequence pictures. However, a significant association was noted between the level of assimilation consistently revealed in stories describing pictured events and the number of pictures (single or sequence of three pictures) used to depict the event. Further study is needed to investigate the influence and the role of sequences in primary mathematics textbooks.

In this study, first graders' interpretations of dynamic pictures were obtained by a verbal response to the direction to tell a story. Hence, part of this study relied upon the students' verbal ability. Investigation of children's interpretations of dynamic pictures portraying mathematical relationships should be studied without a reliance upon verbal responses.

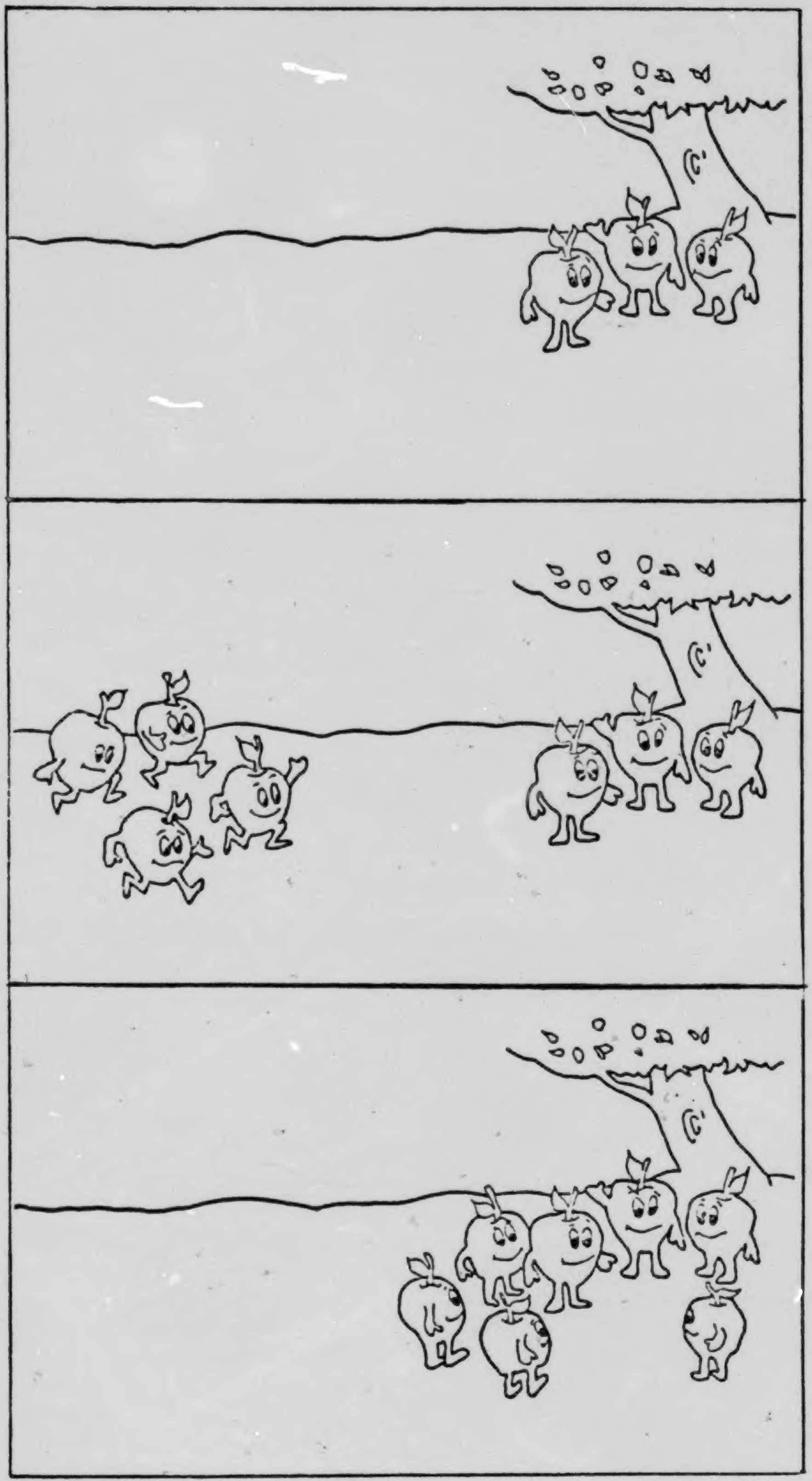
This study presented first grade children with pictures and the students were asked to write or to choose the related number sentence. Follow-up studies are needed to further investigate children's interpretations of dynamic mathematical illustrations using a reverse approach. That is, first or second grade children should be presented with a number sentence and directed to construct a sequence by ordering pictures or to construct a picture with cut-out figures to depict the number sentence.

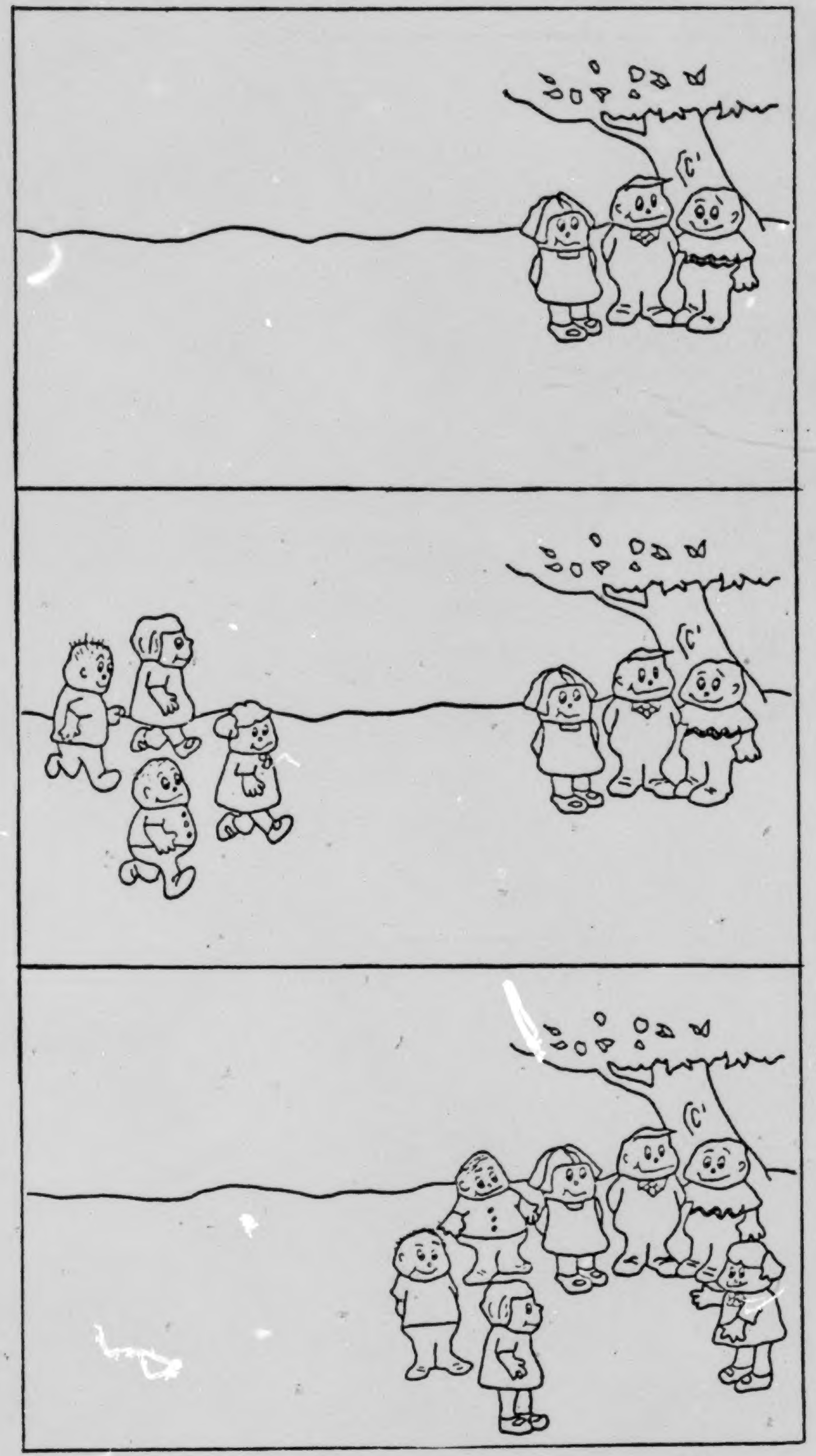
The first graders in this study responded to dynamic textbook-type pictures within a controlled situation. The effect of specific artistic variables upon the children's interpretations of the mathematical relationship depicted in the pictures was investigated. However, in order to determine what artistic variables characterizing illustrations facilitate or hinder the comprehension of the mathematical concepts implied by the pictures, exploratory, clinical studies must be undertaken. Through clinical studies, children may be encouraged to explain pictures in relation to their interpretations, allowing researchers to explore the children's free responses to illustrations and to determine how children perceive mathematical relationships within pictures.

APPENDIX A

PICTURES MAKING UP THE EVALUATION INSTRUMENT

(REDUCED)

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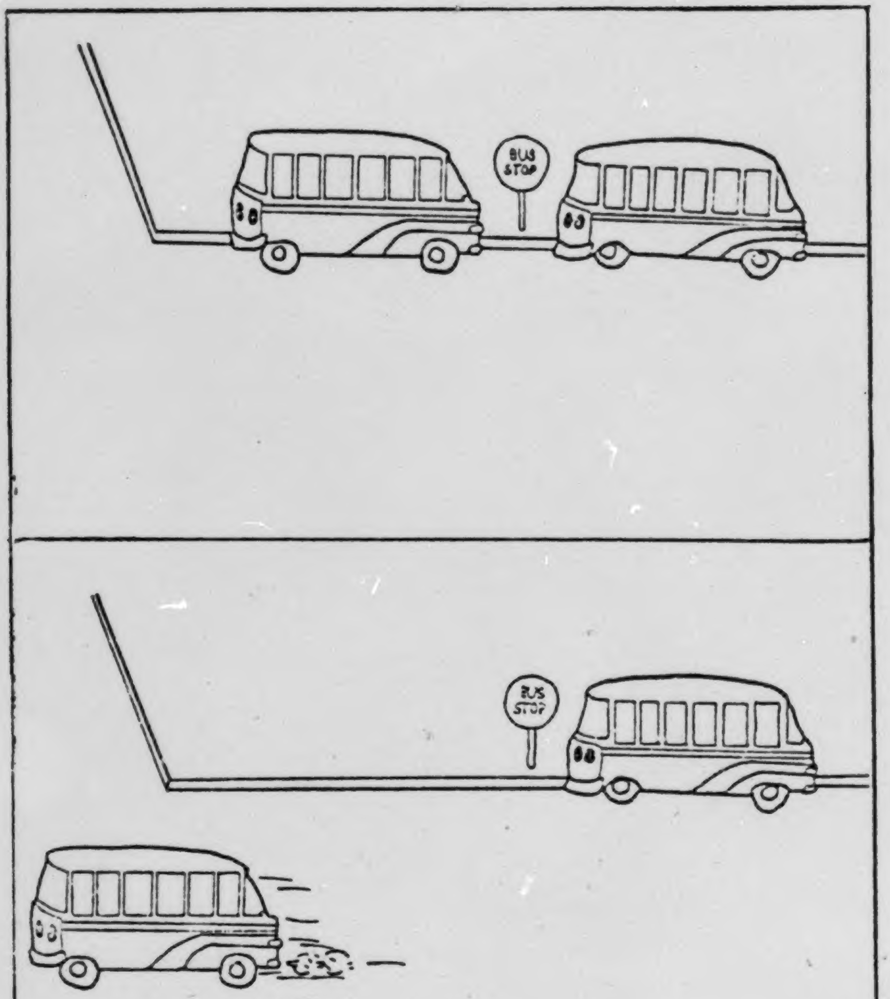
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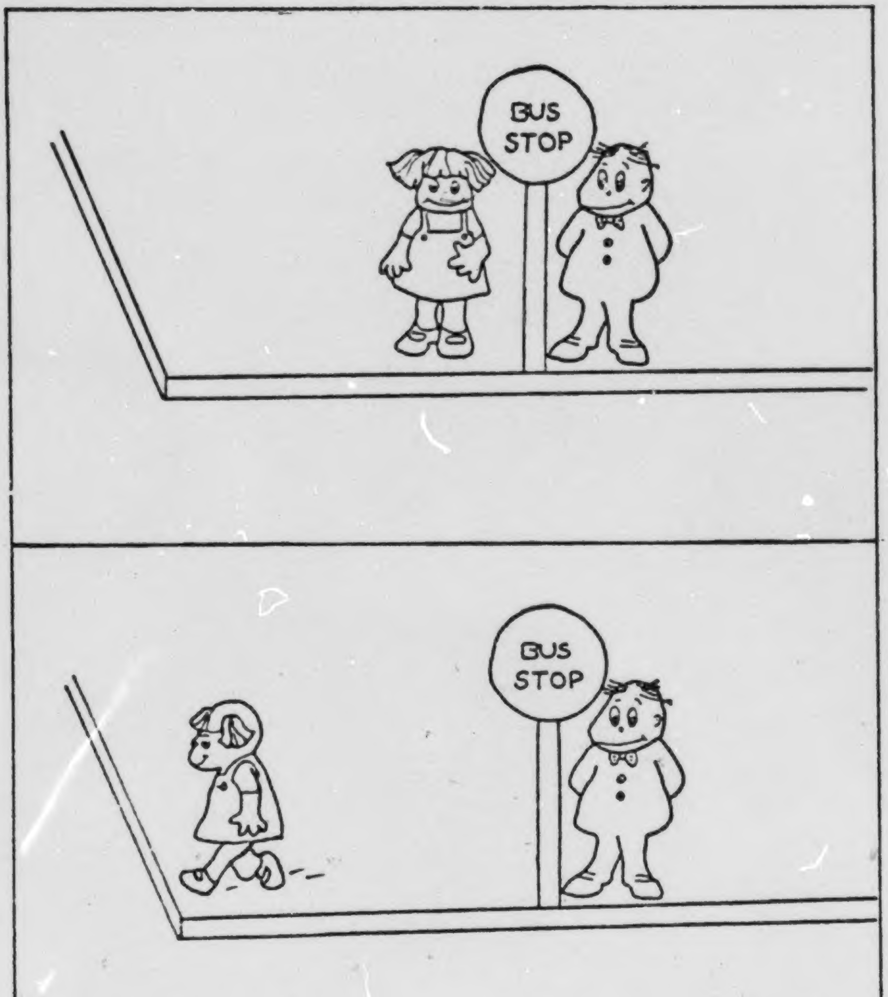
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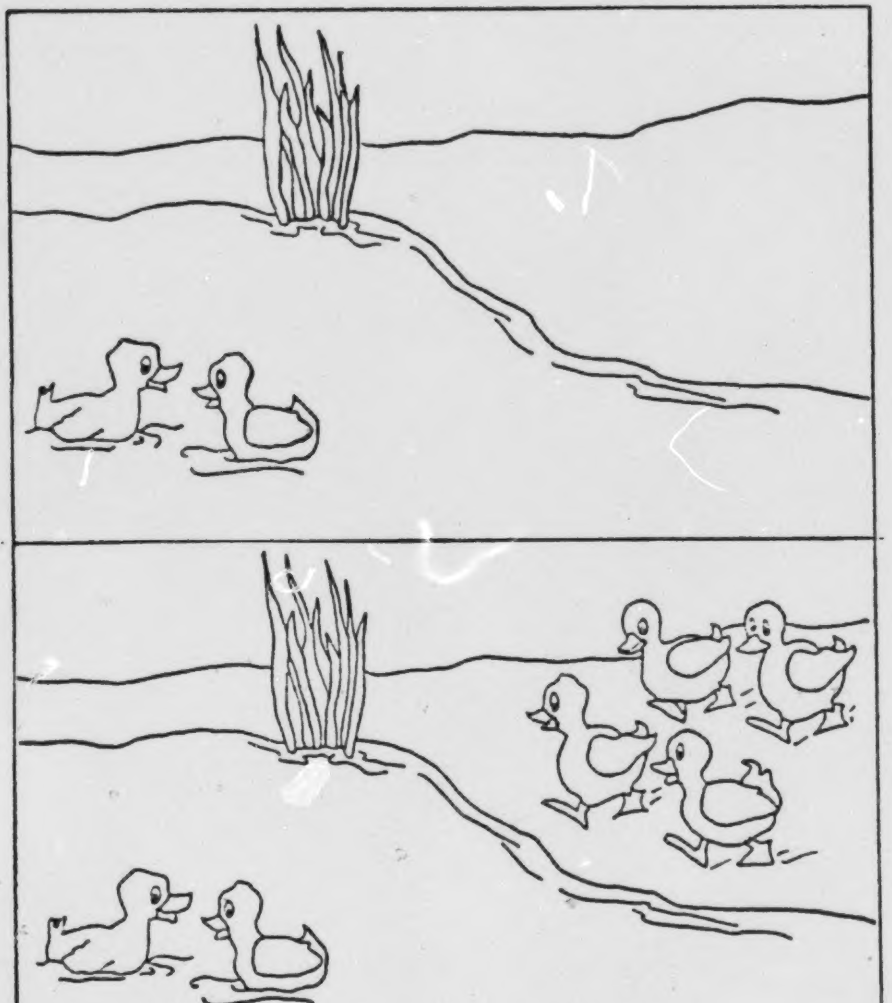

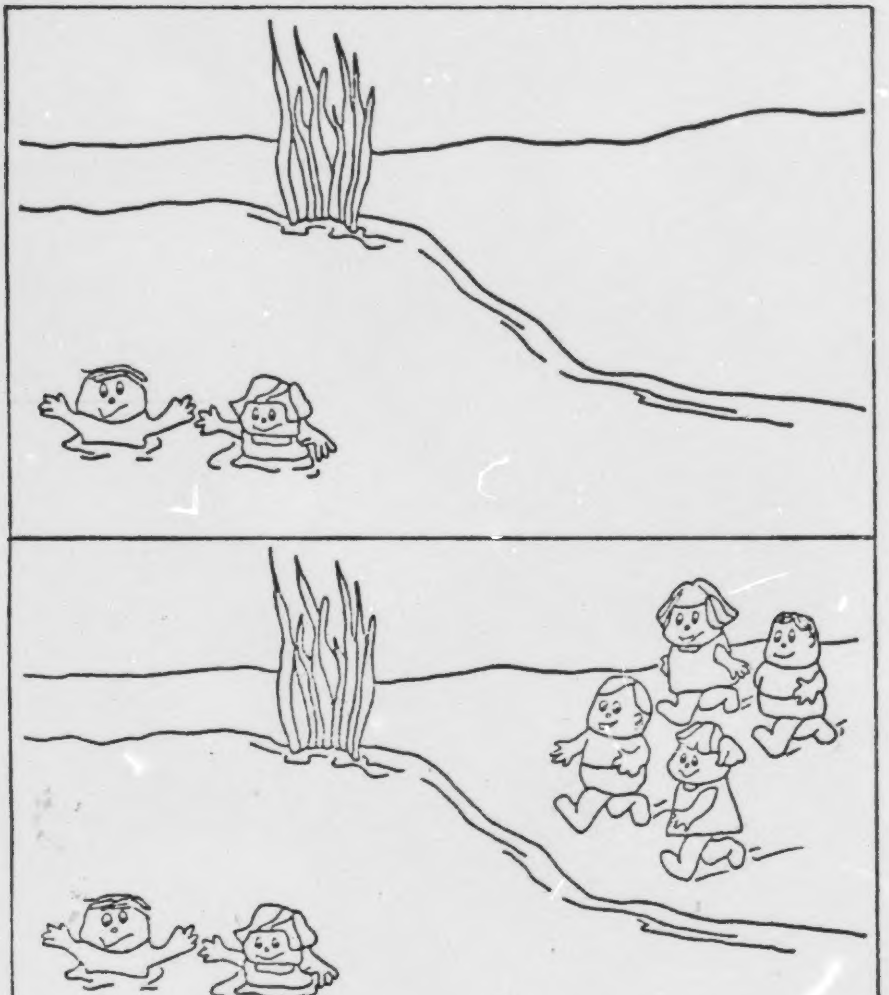

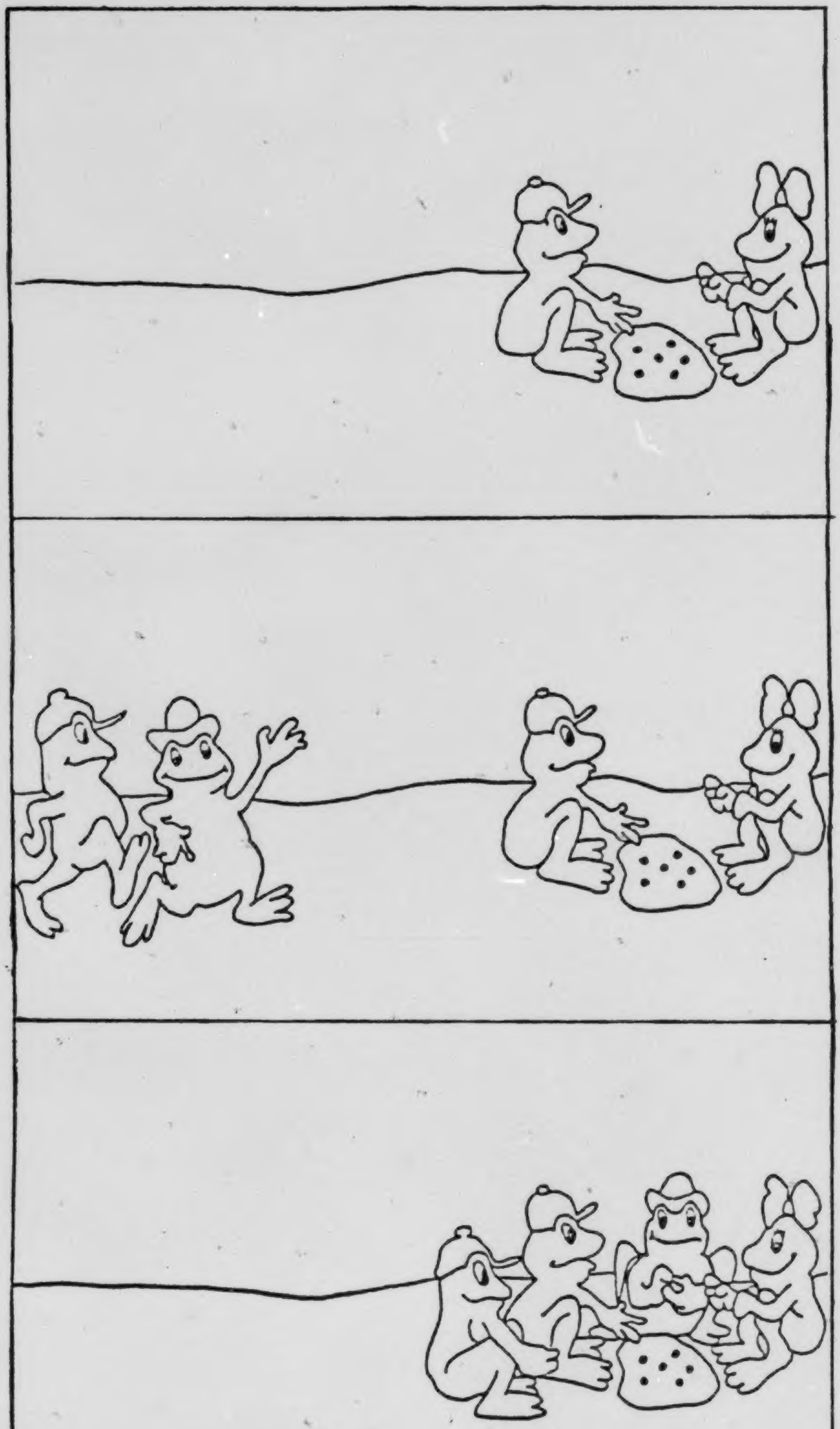

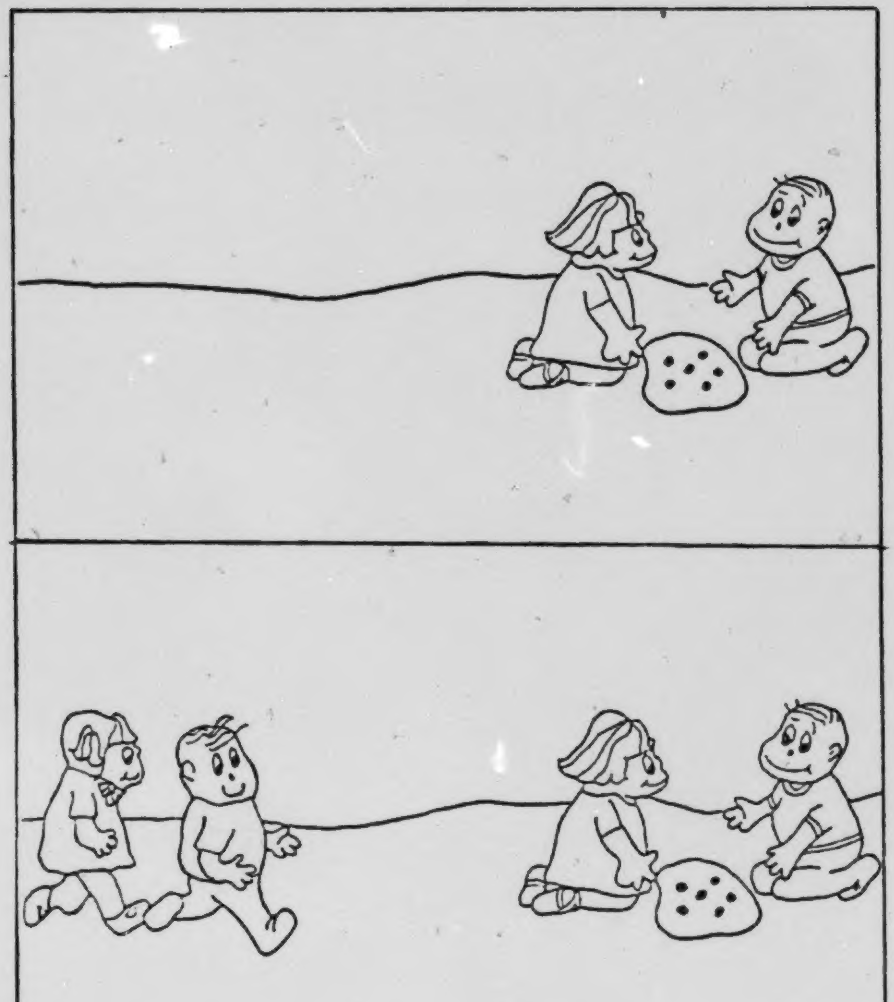

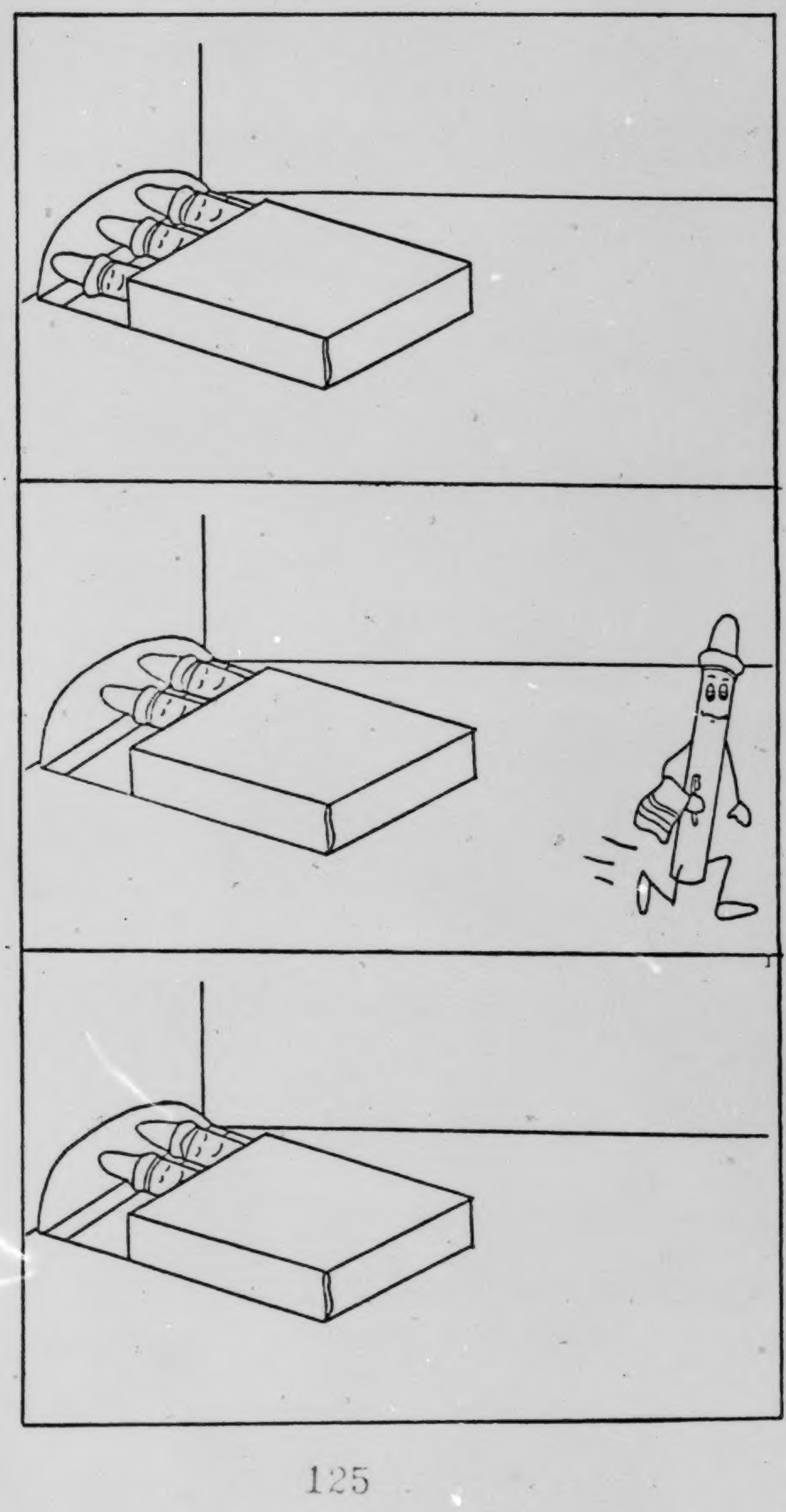

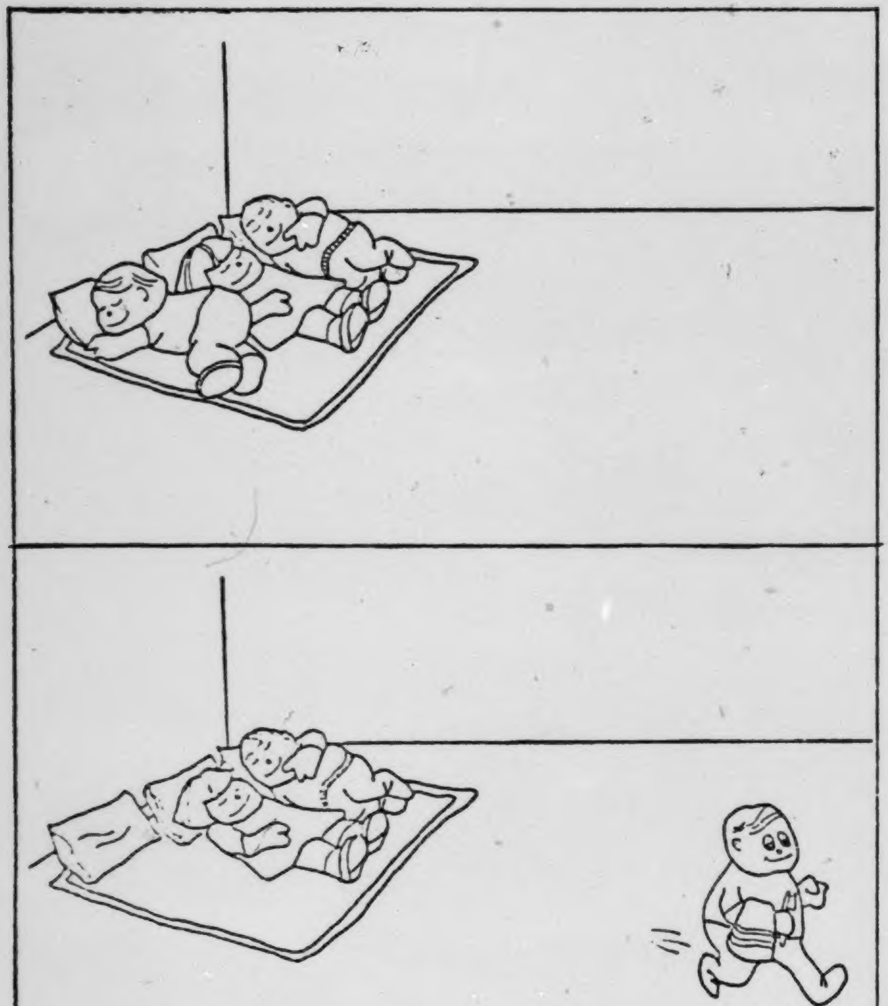

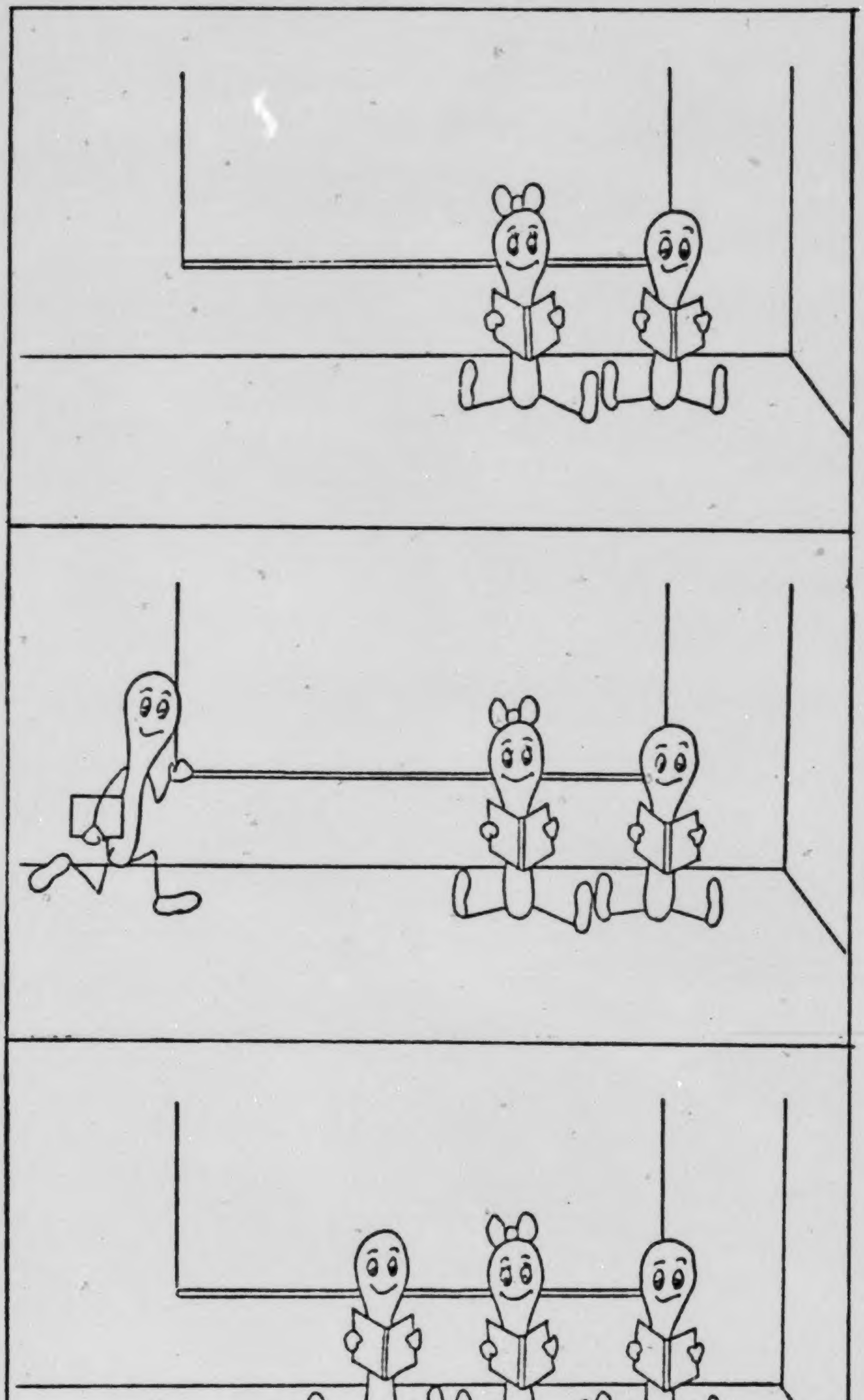

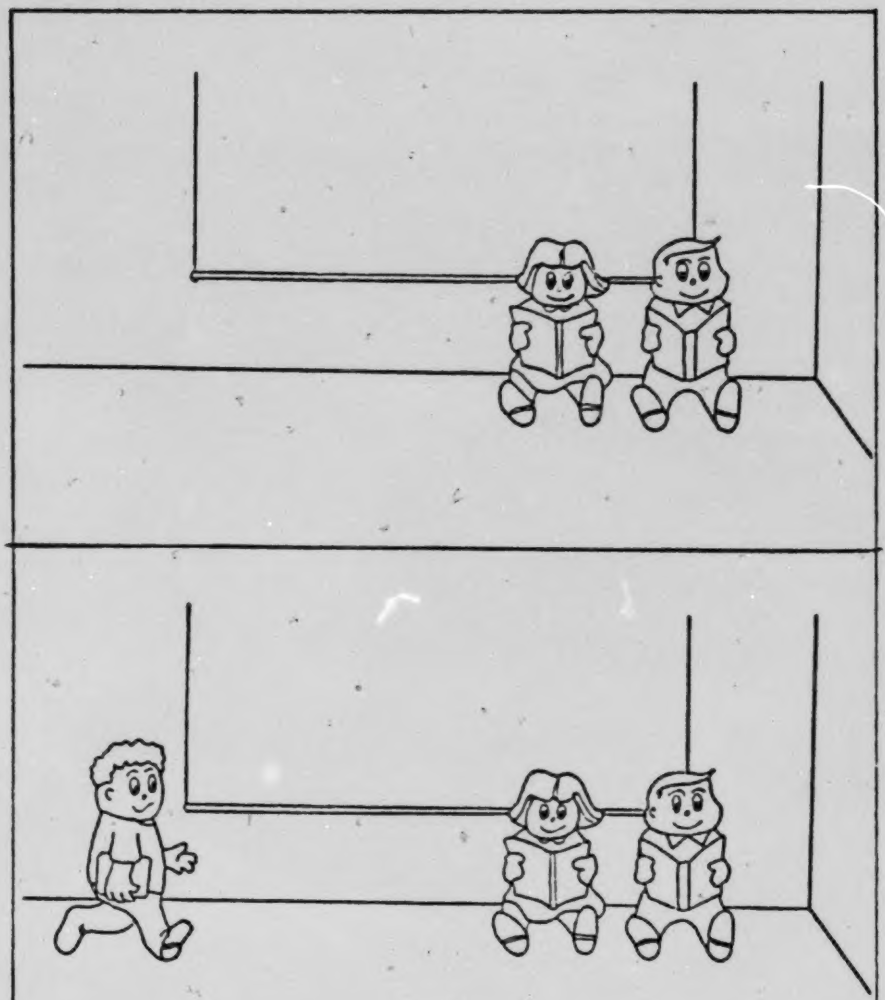

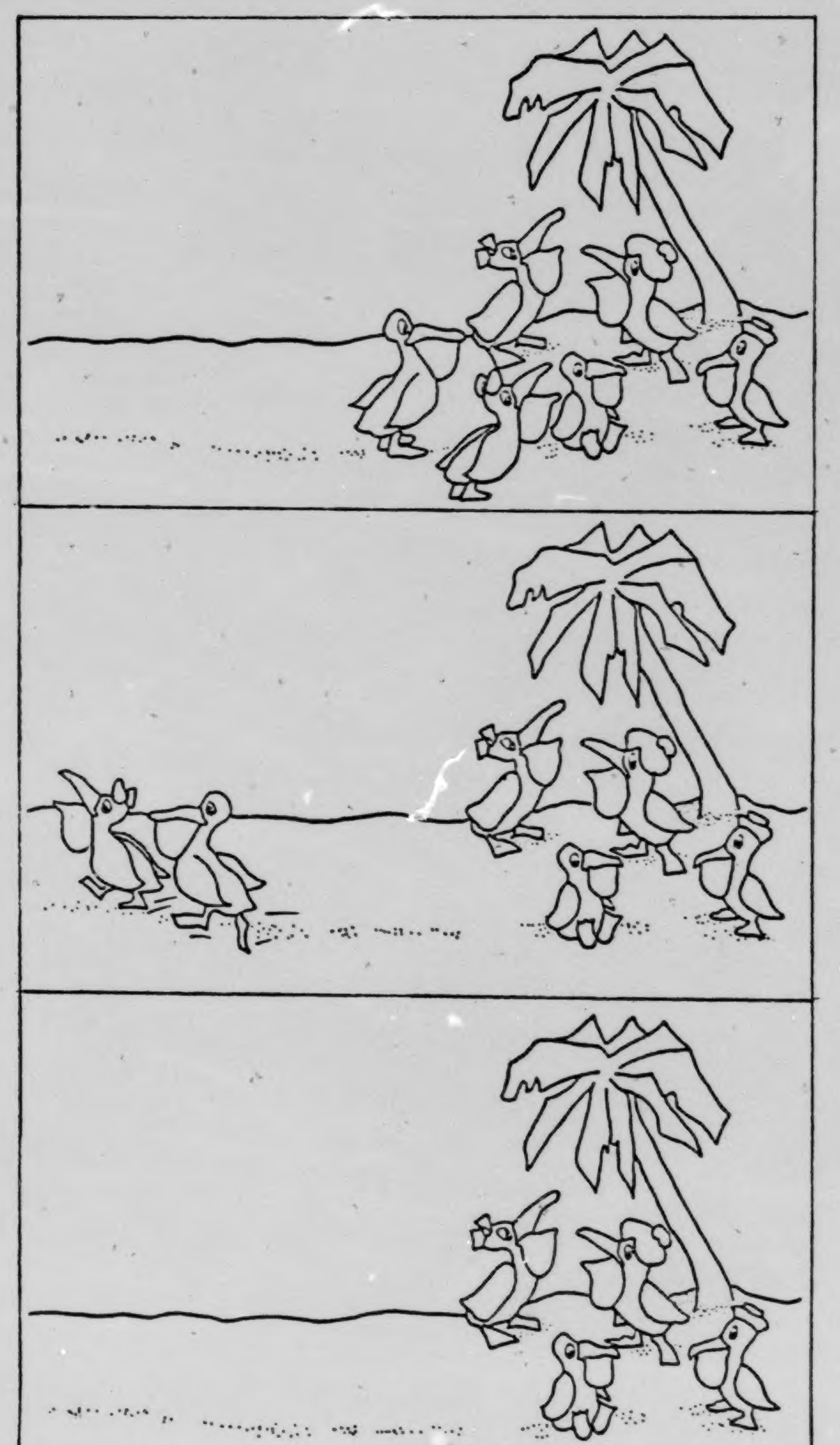

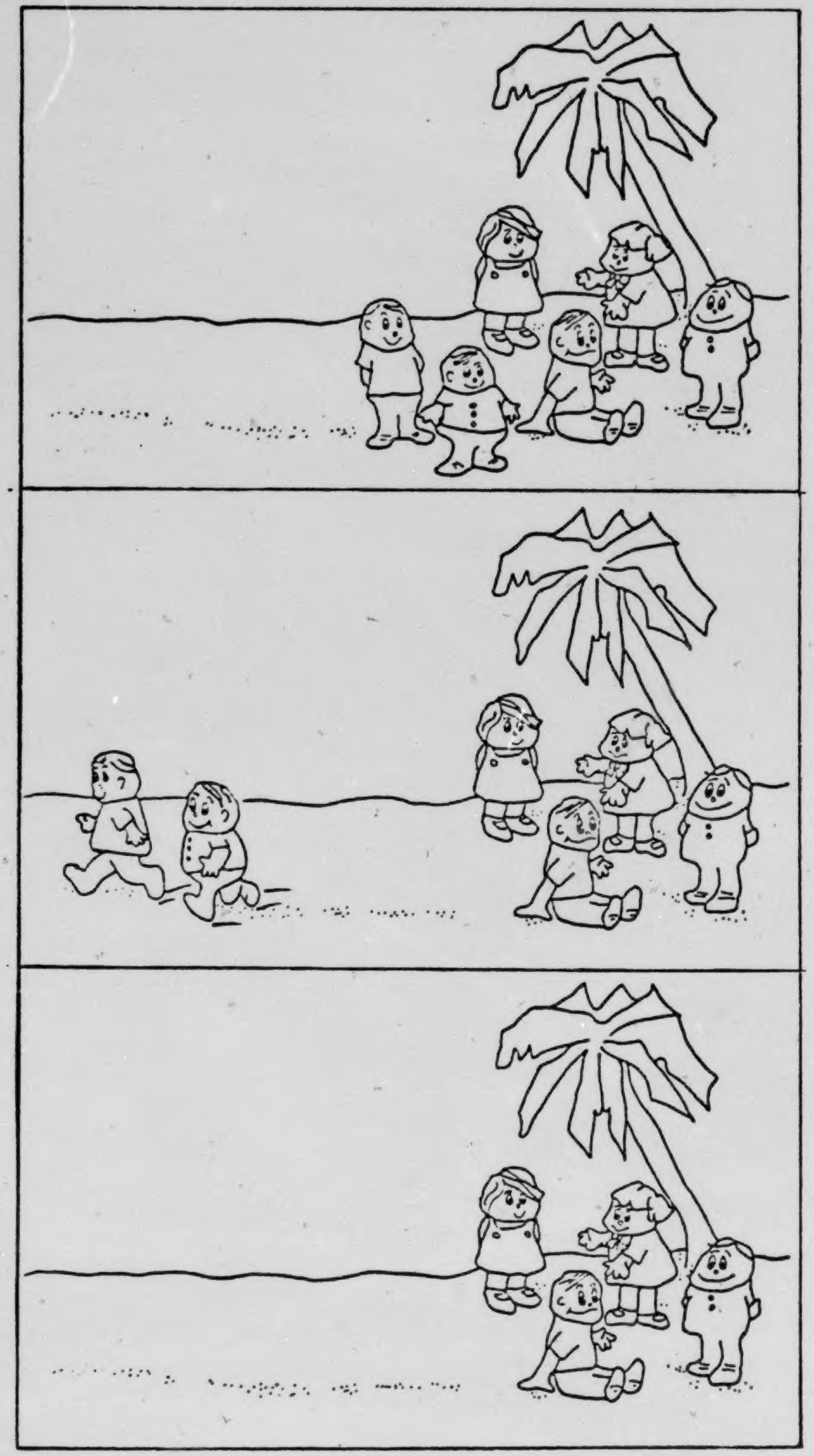

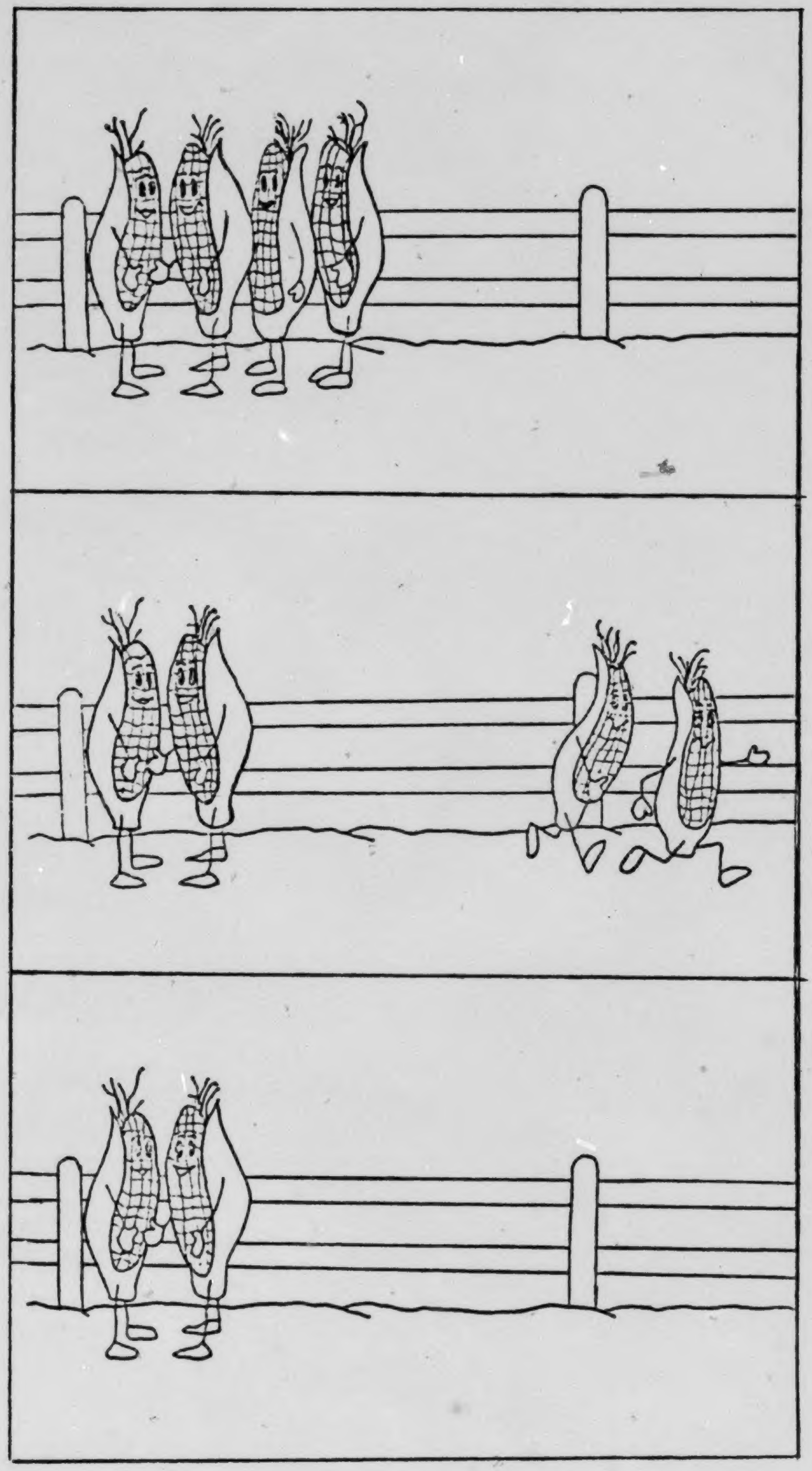

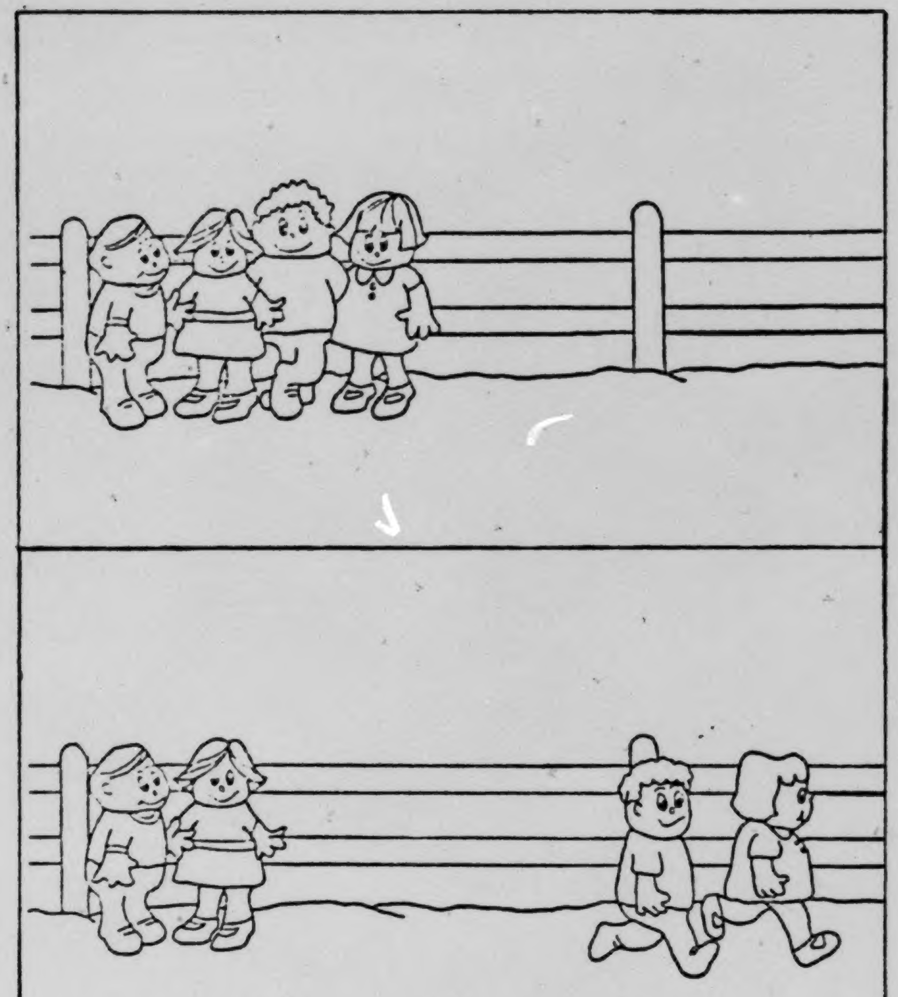

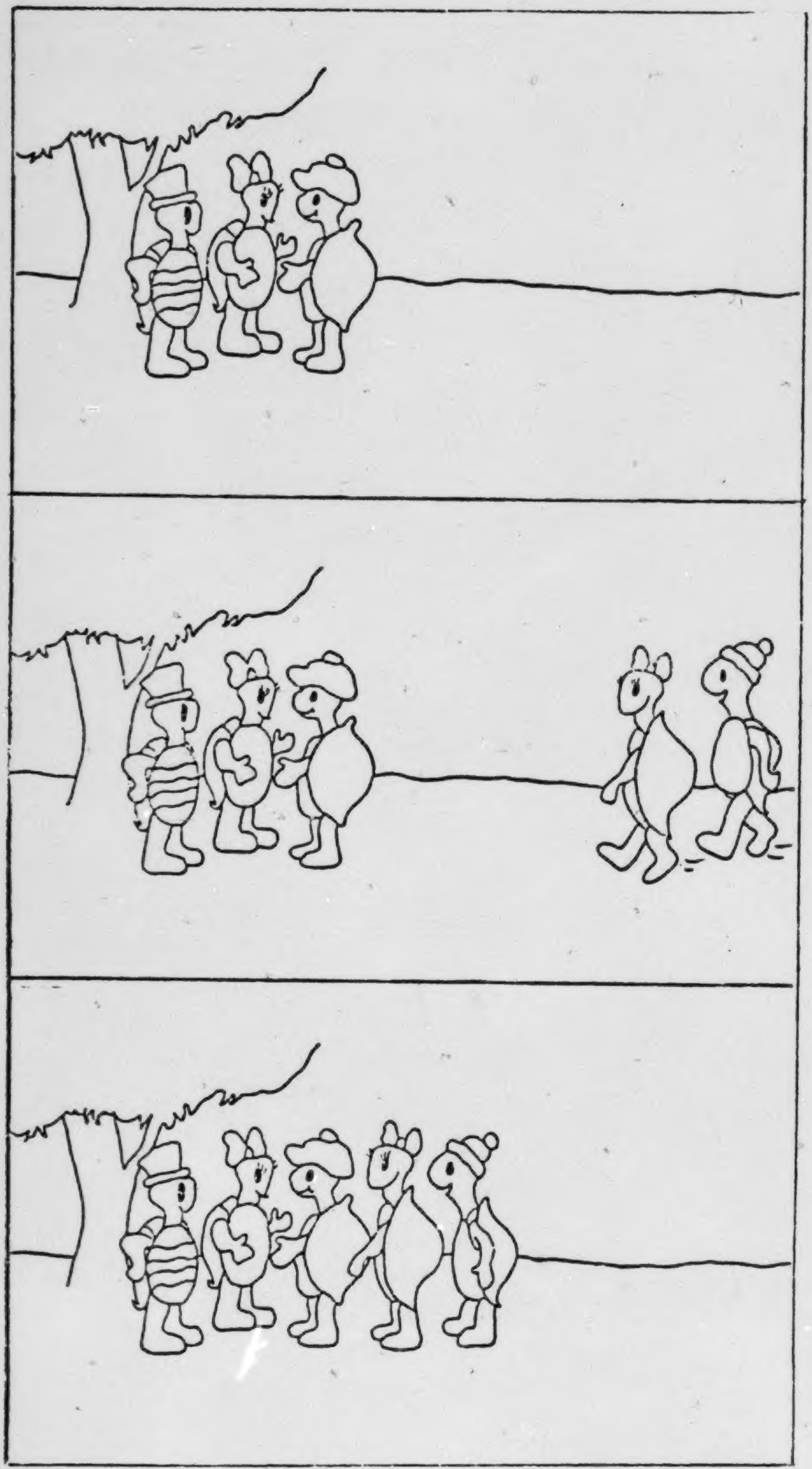

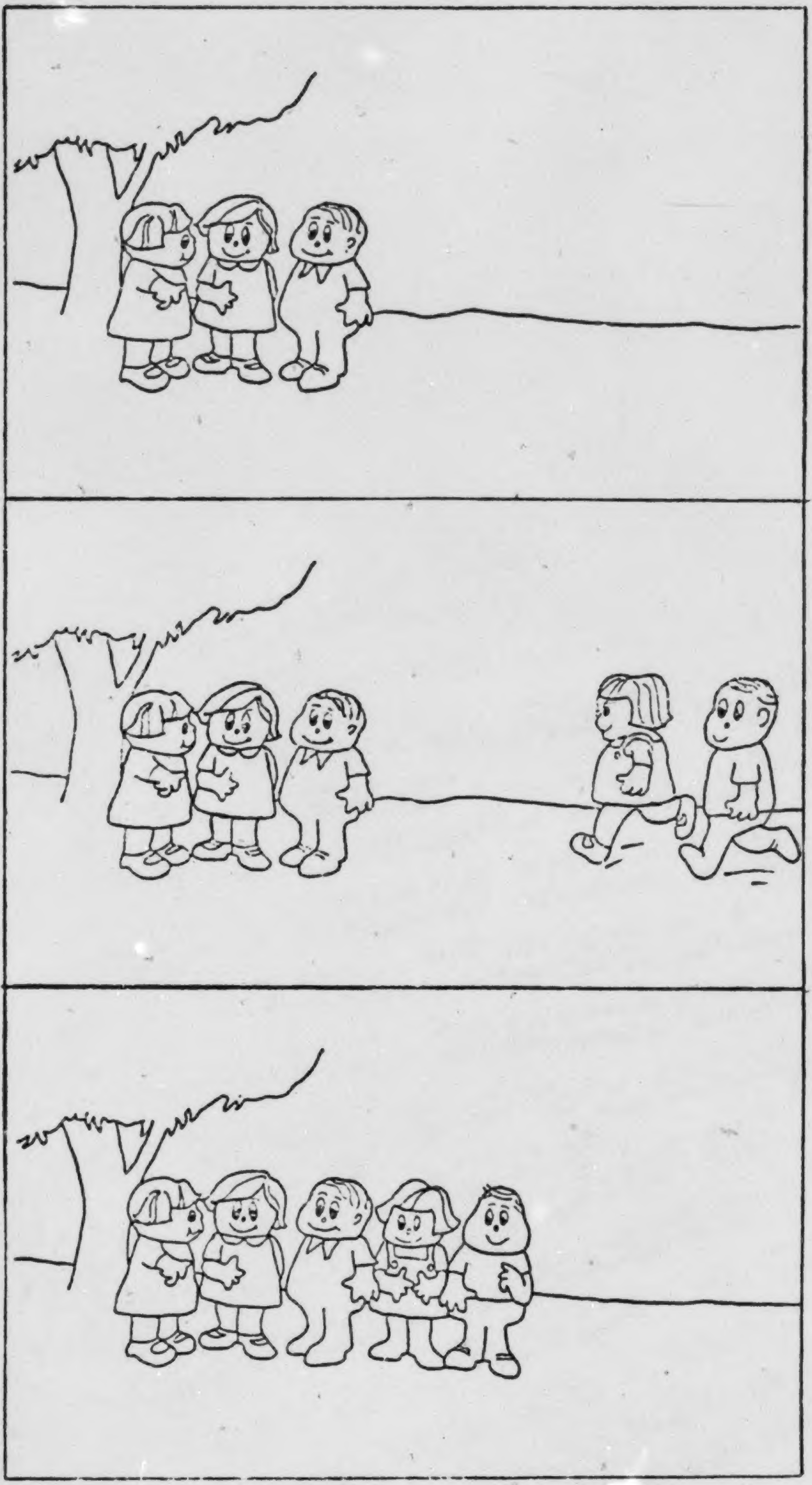

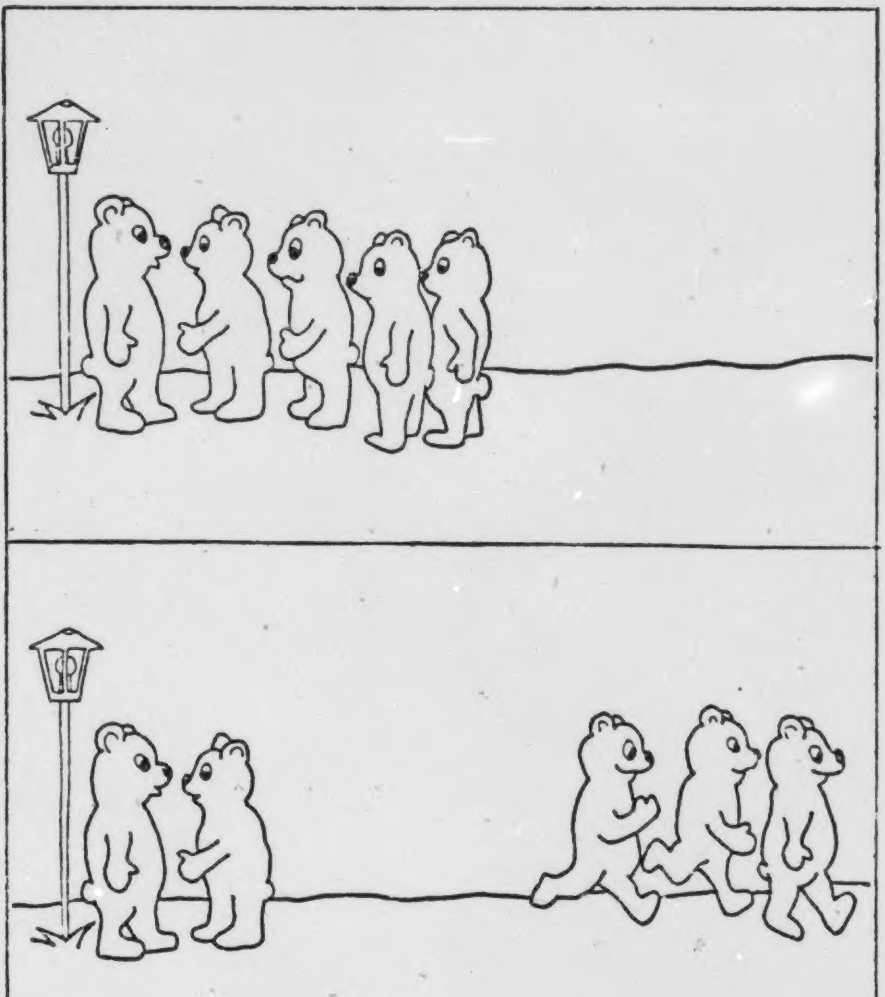

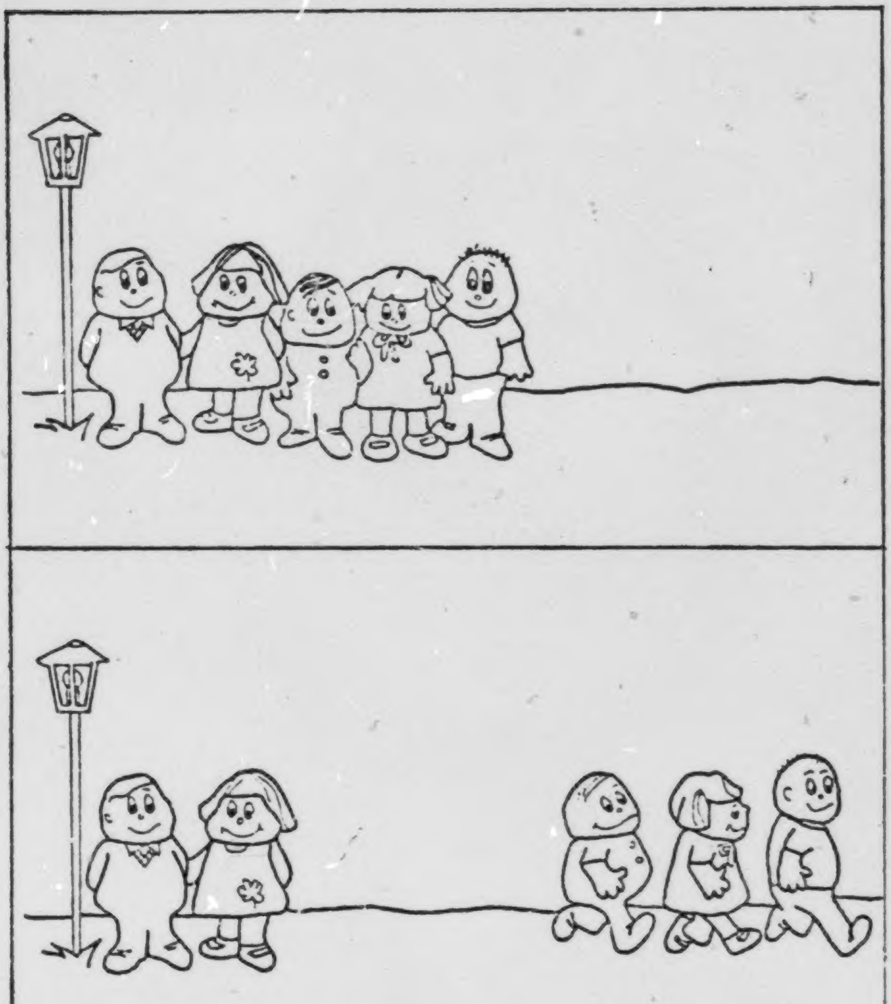

APPENDIX B

RESPONSE FORM

Name____ Sex______

School____________________ Date____________________

Examiner______________________ Teacher______________

Textbook______________________

Type of Picture

___ 10 single realistic pictures

___ 10 sequences of realistic pictures

___ 10 single stylistic pictures

___ 10 sequences of stylistic pictures

___ 5 single realistic pictures; 5 sequences of realistic pictures

___ 5 sequences of realistic pictures; 5 single realistic pictures

___ 5 single stylistic pictures; 5 sequences of stylistic pictures

___ 5 sequences of stylistic pictures; 5 single stylistic pictures

Response Mode

___ Force--choose a number sentence card

___ No Force--write a number sentence

Assimilation

Item 1

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B, but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs used ________________________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 4   3

___ 7 - 4 = 3

___ 3 + 4 = 7

___ 7 + 0 = 7

___ 3   4   3   7

___ Student's written response ____________________________

Comments

Assimilation Item 2

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B, but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs Used ______________________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 2 - 1 = 1

___ 1 1

___ 2 1 1 1

___ 1 - 1 = 1

___ 1 + 1 = 2

___ Student's written response ______________________________

Comments

Assimilation Item 3

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B, but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs used ________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 6 + 0 = 6

___ 2 2 4 6

___ 2 4

___ 6 - 4 = 2

___ 2 + 4 = 6

___ Student's written response ________________

Comments

Assimilation Item 4

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B, but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs used ______________________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 2 + 2 = 4

___ 4 + 0 = 4

___ 2 2 2 4

___ 2 2

___ 4 - 2 = 2

___ Student's written response ____________________________

Comments

Item 5

Assimilation

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B, but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs used ________________________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 2 - 1 = 2

___ 3   2   1   2

___ 2 + 1 = 3

___ 2   2

___ 3 - 1 = 2

___ Student's written response ______________________________

Comments

Assimilation

Item 6

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B, but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs used ____________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 2 1 2 3

___ 1 2

___ 3 - 1 = 2

___ 2 + 1 = 3

___ 3 + 0 = 3

___ Student's written response ____________________

Comments

Assimilation Item 7

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B, but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left). Verbs used ______________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 2 + 4 = 6

___ 4 - 2 = 4

___ 6 - 2 = 4

___ 6 2 4 4

___ 2 4

___ Student's written response ______________________

Comments

Assimilation — Item 8

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B, but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs used ________________________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 2 2

___ 2 + 2 = 4

___ 2 - 2 = 2

___ 4 - 2 = 2

___ 4 2 2 2

___ Student's written response ______________________________

Comments

Assimilation Item 9

___ No attempt to tell a story

___ Identifies only Picture A

___ Identifies only one subset in Picture B

___ Identifies only Picture C

___ Identifies both subsets in Picture B but does not relate the two subsets (enumerates)

___ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

___ Identifies Picture A, Picture B, and Picture C but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

___ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

___ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

___ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

___ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs used ________________

___ No verbal response

Number Sentence

___ No sentence chosen or written

___ 5 - 2 = 3

___ 3 + 2 = 5

___ 5 + 0 = 5

___ 3 3 2 5

___ 3 2

___ Student's written response ________________

Comments

Assimilation

Item 10

____ No attempt to tell a story

____ Identifies only Picture A

____ Identifies only one subset in Picture B

____ Identifies only Picture C

____ Identifies both subsets in Picture B but does not relate the two subsets (enumerates)

____ Identifies both subsets in Picture B and relates the two subsets as a whole (assimilates)

____ Identifies Picture A, Picture B, and Picture C, but does not relate the two subsets in Picture B and does not relate the three pictures (enumerates)

____ Identifies Picture A, Picture B, and Picture C, relates the two subsets in Picture B, but does not relate the three pictures

____ Identifies Picture A, Picture B, and Picture C and relates the three pictures (assimilates)

Motion Perception--Verb Form

____ Uses only forms of the verb "to be;" motion not mentioned (e.g."There are three ducks here and another duck here.")

____ Uses action verbs to denote motion (e.g. walked, came over, left) Verbs used ________________________________

____ No verbal response

Number Sentence

____ No sentence chosen or written

____ 5 2 3 2

____ 5 - 3 = 2

____ 2 3

____ 2 + 3 = 5

____ 2 - 3 = 2

____ Student's written response ____________________________

Comments

APPENDIX C

EXAMINER'S MANUAL

Examiner's Manual

Picture-Number Sentence Test

The purpose of this study is to investigate whether there is a correlation between first grade children's ability to tell a story about a picture or sequence of pictures and their ability to describe the picture or sequence by a number sentence. In particular, the children's stories will be analyzed in terms of the degree to which the stories assimilate the characteristics of the picture or sequence and indicate perception of motion. This instrument has been developed in order to gather data concerning the role of pictures in first grade children's perception of mathematical relationships within the framework outlined above.

Test Materials

Pictures

Each examiner has a set of 20 sequences; each consisting of three pictures. Ten of the sequences portray human figures (realistic) and 10 of the sequences portray personified animals or objects (stylistic). Each stylistic sequence has a corresponding realistic sequence portraying the same mathematical relationship within an identical setting.

Each sequence has been assigned a number from 1 to 20. Within each sequence, the initial picture has been identified as A, the middle picture as B, and the final picture as C. On the back of each picture, an identification code has been noted. For example, the backs of the pictures in the third sequence are identified by 3A, 3B, and 3C.

The set of 10 stylistic picture sequences is arranged in the following order:

1. Sequence of apple pictures (1A, 1B, 1C)
2. Sequence of bus pictures (2A, 2B, 2C)
3. Sequence of duck pictures (3A, 3B, 3C)
4. Sequence of frog pictures (4A, 4B, 4C)
5. Sequence of crayon pictures (5A, 5B, 5C)
6. Sequence of spoon pictures (6A, 6B, 6C)
7. Sequence of pelican pictures (7A, 7B, 7C)
8. Sequence of corn pictures (8A, 8B, 8C)
9. Sequence of turtle pictures (9A, 9B, 9C)
10. Sequence of bear pictures (10A, 10B, 10C)

Their corresponding realistic sequences should be ordered in the same manner from 11A, 11B, 11C through 20A, 20B, 20C.

Number Sentence Cards

Each examiner has a set of five number sentence cards for each sequence of pictures. Each number sentence card has been identified as a, b, c, d, or e. On the back of each number sentence card, an identification code has been noted. For example, the backs of the number sentence cards to correspond with the fifteenth sequence are identified by 15a, 15b, 15c, 15d, 15e.

Response Form

The first page of the response form has space to note the name and the sex of the student, the school, the date, the mathematics textbook being used, the teacher's name, and the examiner's name as well as the type of pictures and response mode being utilized.

For each item of the instrument, there are three response categories to note.

1. The level of assimilation revealed within the student's verbal story; that is, whether the student identifies some or all of the subsets depicted in the picture or sequence and whether the student relates the subsets or pictures.
2. The verb form used by the student when telling a story to describe the picture; in particular, whether the student's story indicates perception of motion within the pictures through the use of action verbs.
3. The number sentence chosen or written by the student to describe the mathematical relationship depicted in the picture or sequence.

The examiner should check (✓) the appropriate response blank in each category, noting the student's written number sentence if the student is in the no force response mode.

If the examiner wishes to elaborate on a student's response or method, he(she) should do so in the comments section for each item. If the student asks a question, note the question in the comments section.

Miscellaneous

Each examiner has a tape recorder to record the administration of the test. A pencil and 10 small blank sheets of paper are also available for each student in the no force response mode.

Test Administration

Test Design

Prior to each testing, the examiner will receive a response form indicating the student's name, as well as the type of pictures and the response mode to be used during the assessment.

The following listing indicates which pictures are to be presented to the students in the various picture types, and the order of presentation.

10 single realistic pictures	11B; 12B; 13B through 20B
10 sequences of realistic pictures	11A, 11B, 11C; 12A, 12B, 12C through 20A, 20B, 20C
10 single stylistic pictures	1B, 2B, 3B through 10B
10 sequences of stylistic pictures	1A, 1B, 1C; 2A, 2B, 2C through 10A, 10B, 10C
5 single realistic pictures; 5 sequences of realistic pictures	11B; 12B through 15B; 16A, 16B, 16C through 20A, 20B, 20C
5 sequences of realistic pictures; 5 single realistic pictures	11A, 11B, 11C through 15A, 15B, 15C; 16B, 17B through

	20B
5 single stylistic pictures; 5 sequences of stylistic pictures	1B, 2B, 3B through 5B; 6A, 6B, 6C through 10A, 10B, 10C
5 sequences of stylistic pictures; 5 single stylistic pictures	1A, 1B, 1C through 5A, 5B, 5C; 6B, 7B, 8B through 10B

Number sentence cards are presented only if the student is in a force response mode. Otherwise, the student is to write a number sentence using the paper and pencil available (no force mode).

Preliminaries

Attempt to put the student at ease. The examiner should introduce himself to the student and engage in a brief conversation. A right handed examiner should seat the student on his left $E\overset{S}{\boxed{}}$; and a left-handed examiner should seat the student on his right $E\underset{S}{\boxed{}}$. Make sure that the student is in fact the student identified on the response form. Prior to each testing record the name of the student on the tape recorder.

The examiner should tell the student that they are going to look at some pictures and that the examiner will ask the student some questions about the pictures. Do not identify the test as a game or a test.

Testing--General

Look at the student and maintain eye contact. The examiner may offer reassurances without specifying whether the student is right or wrong. The examiner may

1. repeat the student's response.
2. murmur "Okay," "Fine," "Alright."
3. smile or nod his head.

The examiner may repeat a question, but should not rephrase a question. The examiner may probe only by using the sentence, "Tell me more." If a student makes no attempt to answer a question after 15 seconds, the examiner should repeat the question. If the student still does not respond, go on to the next question.

Testing--Directions

1. Turn on the tape recorder.
2. Record the student's name on the tape recorder.
3. Place a sequence of pictures (A,B,C) or a single picture (B) horizontally before the student as determined by the test design.

4a. For students viewing a sequence of pictures--Direct the student: "Altogether these pictures tell a story. Tell me a story that goes with these pictures." Pass your hand over the sequence of pictures as you are giving this direction.

4b. For students viewing a single picture--Direct the student: "This picture tells a story. Tell me a story that goes with this picture." Point to the picture as you are giving this direction.

5. Check the appropriate identification on the response

form under Assimilation and Motion Perception--Verb Form.

6a. For students in the force response mode viewing a sequence of pictures, place the corresponding number sentence cards before the student, between the student and the pictures, in the following order: a, b, c, d, e. Direct the student: "Which one of these number sentences is for these pictures altogether?" Make a sweeping motion with your hand over the number sentence cards as you are giving this direction.

6b. For students in the force response mode viewing a single picture, place corresponding number sentence cards before the student, between the student and the picture in the following order: a, b, c, d, e. Direct the student: "Which one of these number sentences is for this picture?" Make a sweeping motion with your hand over the number sentence cards as you are giving this direction.

6c. For students in the no force response mode viewing a sequence of pictures, give the student a pencil and a sheet of paper. Direct the student: "Write a number sentence for these pictures altogether." Make a sweeping motion with your hand over the sequence of pictures as you give this direction. If the student has not responded after 10 seconds, direct the student: "Write numbers for these pictures altogether." Again use a sweeping motion with your hand over the pictures as you give this alternate direction.

6d. For students in the no force response mode viewing a single picture, give the student a pencil and a sheet of paper. Direct the student: "Write a number sentence for this picture." Point to the picture as you give this direction. If the student has not responded after 10 seconds, direct the student: "Write numbers for this picture." Again point to the picture as you give this alternate direction.

7. Note the student's number sentence response on the response form under Number Sentence.

8. Remove the picture(s), the number sentence cards, and the student's paper and pencil. Go back to 3. and repeat until all 10 items are completed.

9. Turn off the tape recorder.

Completion

Thank the student for participating. Since more than one student is being tested in the same room, do not allow the student to disturb the others. Rather, talk quietly with the student until all testing in the room is completed.

APPENDIX D

SELECTED STORY RESPONSES WITH CORRESPONDING LEVEL OF ASSIMILATION AND RESPONSE SCORES

General Story

"Apples grow on a tree. You color them red. The letter 'A' starts with apples." (0 points) (Item 1)

"Momma duck and baby duck go, "Quack, quack, quack.'" (0 points) (Item 3)

"These kids live by a pond and they like to go swimming everyday." (0 points) (Item 3)

Identifies only one subset in Picture B

"They playing. There's three. And they got something on top of their head." (1 point) (Item 1)

"They find something and they don't know what it is." (1 point) (Item 4)

"There's a tree with some apples that, . . . that look like people. The, the apples have, hmmm, legs, and a mouth and, hmmm, feet, hands. . . . And the tree has leaves on it." (1 point) (Item 1)

Identifies both subsets in Picture B, but does not relate the two subsets and does not identify motion (enumeration)

"There's three over there and four others over there and they all want to play together. But they can't get together 'cause . . . I don't know why." (2 points) (Item 1)

"Two . . . one boy and one girl. Then two more boys and then two more girls. And then all of them were four and they were two." (2 points) (Item 3)

"There's two frogs over here and these two frogs . . . I mean, these two frogs are eating nuts. Okay, these frogs are playing and these frogs are still eating. And they never stop eating and they never stop playing." (2 points) (Item 4)

"These are two. . . . And four more." (2 points) (Item 7)

"These two and these three." (2 points) (Item 9)

Identifies both subsets in Picture B, identifies motion, but does not relate the two subsets (enumeration)

"Two frogs are playing marbles and two frogs are walking." (3 points) (Item 4)

"This crayon's going to take a bath. . . . Other crayons are going to sleep. . . . He's sneakin'." (3 points) (Item 5)

"They looking at a book. . . . He running. . . . They looking at a book together. They waiting for the bell, looking at a book. . . . He running." (3 points) (Item 6)

"Once there was four storks and two went away." (3 points) (Item 7) (Student identified the pelicans as storks.)

"Two girls and one boy were standing by the tree. And another boy and girl ran by the tree." (3 points) (Item 9)

"One boy and one girl, hmmm, is waiting for their mother across the street. And, two boys and one girl see their mother walking home so they're going to catch up with her." (3 points) (Item 10)

Identifies both subsets in Picture B and relates the two subsets as a whole, but does not identify motion

"There's two kids swimming. There's four more. . . . Equals six." (3 points) (Item 3)

"There was two kids playing marbles and there was two more. And two plus two equals four." (3 points) (Item 4)

Identifies both subsets in Picture B, relates the two subsets as a whole, and identifies motion (assimilation)

"These kids were walking over here to see these other kids to ask 'em if they want to play with 'em. And they play." (4 points) (Item 1)

"Two people were by the bus stop and then one person walked away." (4 points) (Item 2)

"Let's see. Three people are sleeping in the living room and one little boy forgot to brush his teeth before he went to bed. And so he went up to the bathroom with his toothbrush and towel and brushed his teeth." (4 points) (Item 5)

"A boy and a girl was reading a book and another boy came and sat down with 'em and read a book." (4 points) (Item 6)

"There's six, take away two. . . . Four were left." (4 points) (Item 7)

"There were three turtles outside. And two more came up and that made five." (4 points) (Item 9)

Identifies Picture A, Picture B, and Picture C, but does not identify motion, does not relate the two sets in Picture B, and does not relate the three pictures (enumeration)

"Here's three. And there's four over here. . . . and three over here. And . . . one, two, three, four, five, six, seven. . . . And a tree. (2 points) (Item 1)

"One, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve. Twelve kids standing by a light." (2 points) (Item 10)

"That one has two buses and that one has two buses and they all been stopped. . . . This one's alone." (2 points) (Item 2)

Identifies Picture A, Picture B, and Picture C, identifies motion, but does not relate the two sets in Picture B and does not relate the three pictures (enumeration)

"This one girl's waiting by a sign. And this one boy's waiting by a sign. And this girl's going across the street. And this boy's waiting to go across the street. And he's watching the cars." (3 points) (Item 2)

"Three there and two here. One's leaving and there's two more." (3 points) (Item 5)

"One, two, three, four, five, six. Six here and four there and two are leaving. . . . And there's four there too." (3 points) (Item 7)

"These are standing here in a row. These are talking. These are leaving. These are just two that are talking." (3 points) (Item 8)

"Three. . . . Three there and two are coming. And one, two, three, four, five." (3 points) (Item 9)

"Three children going to bed. And two children going to bed and one got up. . . . Two children going to bed and the one's gone somewhere." (3 points) (Item 5)

Identifies Picture A, Picture B, and Picture C, relates the two sets in Picture B, identifies motion, but does not relate the three pictures

"Two, . . . two kids. . . . Two kids and one went away. . . . A little boy." (3 points) (Item 2)

"There's two all in the pond. There's two and them some more come and so there's lots more. Then there's some more and that's then." (3 points) (Item 3)

"This is a story about two little . . . two girls and one boy (A). One boy came outside and played. And two girls came outside and played. And they sit down, you know, and played? A girl and a boy, two kids, two, came over to play with 'em (B). . . . And then some more came over and play with 'em. And then you had two boys and three girls (C)." (3 points) (Item 9)

Identifies Picture A, Picture B, and PIcture C, relates the two subsets as a whole, identifies motion, and relates the three pictures (assimilation)

"Once there was two ducks and they were, they were talking together. They were still talking and along came four more and they joined 'em in the water." (4 points) (Item 3)

"Two in the water. Four coming and then six in the water." (4 points) (Item 3)

"Once upon a time there was two children playing marbles. They had . . . six marbles in the ring. And then two more came up. And then they all played marbles." (4 points) (Item 4)

"Three children. . . . Wait, . . . three children. One sneaked away and leaves two." (4 points) (Item 5)

"These two kids are reading and one more kid comes and reads with 'em. Then three are all reading together." (4 points) (Item 6)

"One day there was, hmmm, five bears. And three of 'em had to go home and so two of them were left. And so, . . . they, . . . so they played all night." (4 points) (Item 10)

APPENDIX E

NUMBER SENTENCE RESPONSES AND SCORES

Number Sentence Responses and Corresponding Number Sentence Scores for Addition Items

Number Sentence Responses	Number Sentence Score
m + k = p (correct)	4
p - k = m	3
m k p	3
p + 0 = p	2
m m k p	2
m k	2
m p p	1
m	1
k	1
p	1
(m + p + p)	1
no response	0

Number Sentence Response and Corresponding Number Sentence Scores for Subtraction Items

Number Sentence Responses	Number Sentence Score
q - j = i (correct)	4
i + j = q	3
i - j = i	3
q j i	2
j i	2
q i j i	2
q q i	1
j	1
i	1
q	1
(q + q + i)	1
no response	0

APPENDIX F

LEVEL OF ASSIMILATION WITHIN STORY RESPONSES AND CORRESPONDING STORY RESPONSE SCORES

Levels of Assimilation within Story Responses and Corresponding Story Response Scores for Single Pictures

Level of Assimilation	Score
No attempt to tell a story; general title for the story	0
Identifies only one subset in Picture B	1
Identifies both subsets in Picture B, but does not relate the two subsets and does not identify motion (enumeration)	2
Identifies both subsets in Picture B and identifies motion, but does not relate the two subsets (enumeration)	3
Identifies both subsets in Picture B and relates the two subsets, but does not identify motion	3
Identifies both subsets in Picture B, relates the two subsets, and identifies motion (assimilation)	4

Levels of Assimilation within Story Responses and Corresponding Story Response Scores for Sequences

Level of Assimilation	Score
No attempt to tell a story; general title for the story	0
Identifies only Picture A	1
Identifies only Picture C	1
Identifies only one subset in Picture B	1
Identifies Picture A, Picture B, and Picture C, but does not identify motion, does not relate the two sets in Picture B, and does not relate the three pictures (enumeration)	2
Identifies Picture A, Picture B, and Picture C, identifies motion, but does not relate the two sets in Picture B and does not relate the three pictures (enumeration)	3
Identifies Picture A, Picture B, and Picture C, relates the two sets in Picture B, identifies motion, but does not relate the three pictures	3
Identifies Picture A, Picture B, and Picture C relates the two subsets as a whole, identifies motion, and relates the three pictures (assimilation)	4

APPENDIX G

SCORES FOR THE SUBJECTS

Cell	Story Response Scores	Motion Perception Scores	Number Sentence Scores
R_1F	0 3 3 4 3 4 3 3 3 3	0 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2
	3 4 2 2 4 4 4 4 4 4	1 1 0 0 1 1 1 1 1 1	2 4 2 2 2 2 2 2 2 2
	1 4 3 3 4 3 3 4 4 2	0 1 0 0 1 0 0 1 1 1	4 3 4 4 3 4 3 3 4 3
	4 4 3 3 4 3 4 4 4 4	1 1 0 0 1 0 1 1 1 1	4 4 4 4 4 4 4 4 4 4
	2 2 2 2 2 2 2 2 2 2	0 0 0 0 0 0 0 0 0 0	2 3 3 3 3 4 2 4 2 2
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	4 4 3 4 4 4 3 4 4 4
R_3F	3 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 4 4 4 4 4 4 4 4 4
	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	2 2 2 2 2 2 2 2 2 2
	1 3 4 3 4 4 4 3 4 4	0 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 4
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	3 4 2 2 3 4 4 2 4 4
	4 4 3 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 2 4 4 4 4 4 3 4 4
	3 3 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2
R_1R_3F	0 3 4 1 4 4 2 4 2 4	0 1 1 0 1 1 0 1 0 1	4 4 3 3 2 3 3 2 2 3
	3 2 4 4 4 4 4 4 4 4	1 0 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2
	1 3 4 4 4 3 3 3 3 2	0 1 1 1 1 1 1 1 1 0	0 2 3 2 3 4 4 3 3 3
	4 3 3 4 4 4 4 4 4 4	1 1 0 1 1 1 1 1 1 1	4 3 4 4 4 2 4 4 4 4
	2 2 2 2 2 2 2 2 2 2	0 0 0 0 0 0 0 0 0 0	2 2 3 0 0 4 2 2 2 2
	4 3 4 3 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 2 2 2 4 4 4 3 4 4
R_3R_1F	3 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 3 4 4 4 4 4 3 4 4
	3 3 4 3 4 3 3 4 4 4	1 1 1 1 1 1 1 1 1 1	4 3 4 2 4 3 3 2 2 3
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 4 2 2 2 4 3 4 2 2
	0 2 4 2 3 4 3 3 4 3	0 1 1 0 1 1 1 1 1 1	2 2 2 2 2 0 0 0 0 0
	0 3 0 1 3 4 4 3 4 4	0 1 0 0 1 1 1 0 1 1	2 2 2 4 4 4 2 3 2 4
	3 3 2 4 4 3 3 3 4 3	1 1 0 1 1 1 1 1 1 1	4 3 4 4 4 2 4 3 2 2
S_1F	4 2 4 4 4 4 3 3 4 4	1 0 1 1 1 1 1 1 1 1	2 3 2 4 3 4 3 3 4 4
	1 2 3 4 3 1 3 2 3 3	0 1 1 1 1 0 1 0 1 1	2 4 3 3 4 3 4 4 3 3
	3 3 2 3 3 3 3 3 3 3	1 1 0 1 1 1 1 1 1 1	2 2 2 3 2 2 3 2 2 2
	3 3 4 4 3 4 4 4 4 3	1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2
	1 2 2 1 3 3 4 3 4 4	0 0 0 0 1 1 1 1 1 1	4 2 4 3 3 2 3 0 2 3
	2 3 4 2 3 4 4 2 3 4	0 1 1 0 1 1 1 0 0 1	4 3 4 4 3 4 4 3 4 3

Cell	Story Response Scores	Motion Perception Scores	Number Sentence Scores
R_1R_3NF	0 2 1 0 4 4 4 4 4 4	0 0 0 0 1 1 1 1 1 1	0 1 1 1 1 1 0 0 0 0
	2 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 2 2 3 3 3 3 3 3 2
	4 2 3 2 3 3 3 3 3 4	1 0 1 0 1 1 1 1 1 1	1 1 0 1 1 1 1 1 1 1
	1 3 0 4 4 4 4 4 4 4	0 1 0 1 1 1 1 1 1 1	0 1 1 1 2 1 1 1 0 0
	4 3 4 4 4 4 3 3 3 3	1 1 1 1 1 1 1 1 1 1	1 0 0 0 0 1 0 0 0 0
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 3 2 2 3 3 3 3 3 3
R_3R_1NF	4 4 4 4 4 4 4 4 4 3	1 1 1 1 1 1 1 1 1 1	3 3 3 3 2 2 2 2 3 3
	4 4 4 4 4 4 4 3 3 4	1 1 1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0
	0 0 4 4 4 4 4 4 4 4	0 0 1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0
	2 2 2 2 2 4 3 3 3 3	0 0 0 0 0 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	0 4 4 4 4 4 4 4 4 4
	4 4 4 4 4 4 3 3 3 3	1 1 1 1 1 1 1 1 1 1	2 1 1 1 1 2 2 2 2 2
S_1NF	4 3 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	0 1 1 1 1 1 1 1 1 1
	1 3 1 1 3 2 1 1 2 2	0 1 0 0 0 0 0 0 0 0	1 2 1 1 2 2 2 2 2 2
	4 3 3 3 3 4 3 3 3 3	1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2
	1 2 4 3 4 4 1 4 1 4	0 1 1 1 1 1 0 1 0 1	1 1 1 1 1 1 1 1 1 1
	4 3 4 4 3 3 3 3 3 3	1 1 1 1 1 1 1 1 1 1	1 0 0 0 0 0 0 0 1 1
	3 3 3 4 4 4 4 3 4 1	1 1 1 1 1 1 1 1 1 0	2 4 4 4 3 3 3 3 4 3
S_3NF	0 0 4 2 2 3 3 4 3 3	0 0 1 0 0 1 1 1 1 1	0 0 1 0 1 0 1 0 0 0
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	4 4 4 4 4 4 4 4 4 4
	2 3 4 3 2 4 2 2 2 3	0 1 1 0 0 1 0 0 0 1	0 0 0 0 0 0 0 0 0 0
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	3 3 3 1 3 3 3 3 3 3
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	3 3 3 3 3 3 1 3 3 1
	4 4 4 4 4 4 3 4 4 3	1 1 1 1 1 1 1 1 1 1	0 1 1 2 1 1 1 2 1 1
S_1S_3NF	0 0 0 2 2 2 2 2 2 2	0 0 0 0 0 0 0 0 0 0	1 1 1 4 1 1 1 0 1 1
	3 3 3 3 4 3 3 3 3 3	1 1 1 0 1 0 1 1 1 1	2 2 2 2 2 1 2 1 0 1
	0 0 4 0 0 4 4 0 4 4	0 0 1 0 0 1 1 0 1 1	0 0 0 0 0 0 0 0 0 0
	3 2 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 3 2 1 3 3 3 3 3 3
	4 3 4 3 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	1 0 1 0 0 0 1 1 1 1
	2 2 2 2 4 4 2 3 2 3	0 0 0 0 1 1 0 1 0 1	4 0 4 4 3 1 1 1 1 1

Cell	Story Response Scores	Motion Perception Scores	Number Sentence Scores
S_3F	2 4 4 4 3 3 4 4 4 4	0 1 1 1 1 1 1 1 1 1	2 2 2 4 2 2 2 2 2 2
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 3 2 2 2 2 2 2 2 2
	4 3 4 4 4 4 4 2 3 4	1 1 1 1 1 1 1 0 1 1	0 2 2 2 2 3 4 3 4 3
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	4 3 4 4 4 4 4 3 4 3
	1 1 2 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0	2 4 3 3 3 2 3 3 2 3
	3 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 4 2 2 2 4 4 2 4 2
S_1S_3F	4 2 4 4 2 3 4 4 3 4	1 0 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2
	4 3 4 3 4 3 3 4 3 3	1 1 1 0 1 1 1 1 1 1	2 2 2 2 2 2 4 3 2 2
	4 4 4 4 4 4 4 3 4 3	1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 4 4 4 2 4
	0 0 0 0 1 3 1 1 1 1	0 1 0 1 0 1 0 0 0 0	2 4 2 4 3 2 3 2 3 2
	4 3 3 4 4 3 3 3 3 3	1 1 1 1 1 1 1 1 1 1	2 2 2 2 3 2 2 2 3 4
	4 3 3 4 4 4 4 4 4 3	1 1 1 1 1 1 1 1 1 1	4 2 2 2 4 4 4 3 2 2
S_3S_1F	3 4 4 4 4 4 4 3 4 4	1 1 1 1 1 1 1 1 1 1	3 4 2 2 2 2 0 0 0 0
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	3 3 3 2 2 3 2 2 0 2
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	4 3 4 3 2 4 2 0 2 3
	4 4 4 4 4 4 3 4 4 3	1 1 1 1 1 1 1 1 1 1	2 4 2 2 4 2 3 3 2 2
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	4 2 2 4 4 4 4 3 4 3
	4 3 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 4 4 4 4
R_1NF	2 3 2 3 4 3 4 4 3 4	1 1 1 1 1 1 1 1 1 1	1 1 1 0 1 1 1 0 1 0
	4 4 4 4 4 4 4 4 4 4	1 1 1 1 1 1 1 1 1 1	4 4 4 4 4 4 4 4 4 4
	4 4 4 4 4 4 4 4 4 3	1 1 1 1 1 1 1 1 1 1	1 2 0 1 2 2 1 2 2 1
	3 3 3 3 3 3 3 3 3 3	1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2
	0 0 3 1 4 2 4 3 4 3	0 0 1 0 1 0 1 1 1 1	0 0 0 0 0 0 1 0 0 0
	0 0 4 3 4 3 3 3 3 3	0 0 1 1 1 1 1 1 1 1	1 1 1 0 0 0 0 1 1 1
R_3NF	2 3 3 3 3 3 3 3 3 3	0 1 1 1 1 1 1 1 1 1	4 4 4 4 4 4 4 4 4 4
	2 3 3 4 4 4 4 4 4 4	0 1 1 1 1 1 1 1 1 1	1 0 0 0 0 0 0 0 0 0
	0 4 3 4 4 4 4 4 4 4	0 1 0 1 1 1 1 1 1 1	3 3 3 3 3 3 3 3 3 3
	1 3 2 2 1 1 1 1 2 2	0 1 0 0 0 0 0 0 0 0	1 2 2 2 1 1 1 1 2 2
	3 3 4 4 4 4 4 3 4 4	1 1 1 1 1 1 1 1 1 1	0 1 0 0 0 0 0 1 0 0
	1 1 2 1 1 2 3 1 1 1	0 0 0 0 0 0 1 0 0 0	1 1 1 1 1 1 1 1 1 1

Cell	Story Response Scores	Motion Perception Scores	Number Sentence Scores
S_3S_1NF	4 4 4 4 4 4 4 3 4 3	1 1 1 1 1 1 1 1 1 1	3 4 4 4 4 4 4 3 4 3
	2 3 4 4 4 4 4 3 4 3	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 0 1 1 0 1
	4 4 4 4 4 4 3 4 4 4	1 1 1 1 1 1 1 1 1 1	4 1 4 4 4 4 3 2 4 4
	1 1 1 1 3 2 3 3 4 4	0 0 0 0 1 0 1 1 1 1	1 1 1 1 1 1 0 0 1 0
	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	2 1 2 2 1 1 1 1 1 1
	4 3 4 4 4 4 3 3 4 4	1 1 1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0

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